BIOLOGICAL ESCAPEMENT GOALS FOR YUKON RIVER FALL CHUM SALMON

By:

Douglas M. Eggers

Regional Information[1] Report No. 3A01-10

Alaska Department of Fish and Game
Division of Commercial Fisheries, AYK Region
333 Raspberry Road
Anchorage, Alaska 99518

March 31, 2001

1 The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

AUTHOR

Douglas M. Eggers is Chief Fishery Scientist for the Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 25525, Juneau Alaska, 99802-5526.

ACKNOWLEDGMENTS

The author thanks the many field staff of ADF&G who have persevered through hardships with weather, bears, and people in the collection of the escapement, harvest, and age data, which formed the foundation for this paper. I thank Bonnie Borba for her assistance with putting data together and her helpful reviews of drafts of the report. I also thank John Clark for reviews of an early draft of the report. Steve Fleishman provided statistical advice and assistance with fitting the auto-regressive model. The idea and motivation for reconstructing the Yukon River fall chum salmon runs in the manner of this report was due to Louie Barton.

OEO/ADA STATEMENT

TABLE OF CONTENTS

Page

AUTHOR i

ACKNOWLEDGMENTS i

LIST OF TABLES iii

LIST OF FIGURES v

ABSTRACT 1

INTRODUCTION 2

YUKON RIVER FALL CHUM SALMON ESCAPEMENTS, HARVESTS, AND RUNS 5

Yukon River Fall Chum Salmon Escapements 5
Tanana River Escapement 5
Upper Yukon River Tributaries Escapement 5
Upper Yukon River Mainstem Escapement 6
Yukon River Fall Chum Salmon Harvests 6
Age Composition of Annual Escapements and Runs 7
Reconstructed Total Runs of Yukon Fall Chum Salmon 7
General Model of Yukon River Fall Chum Salmon Runs 7
Stock Identification of Harvests 8
Estimation of Recruits from Parent Escapement by Age 11

SPAWNER-RECRUIT RELATIONSHIPS FOR YUKON RIVER ORIGIN FALL CHUM SALMON 12

Methods 12
Spawner-Recruit Relationship and Biological Escapement Goals. 14
Aggregate Yukon River Fall Chum Salmon 14
Tanana River Fall Chum Salmon 17
Upper Yukon River Tributary Fall Chum Salmon 18
Upper Yukon River Mainstem Fall Chum Salmon 21

STATUS OF YUKON RIVER FALL CHUM SALMON STOCKS GIVEN THE RECOMMENDED MSY ESCAPEMENT GOALS 25

RECOMMENDATIONS 26

LITERATURE CITED 28

LIST OF TABLES

Table		Page
1.	Historical escapement of fall chum salmon in the Tanana River. Figures in bold italics were estimated, see text for methods.	31
2.	Retrospective performance of estimating Upper Tanana River Escapement based on expansion of Delta River escapement by 8.13 (= 1/0.123).	32
3.	Historical escapement of fall chum salmon in the Upper Yukon River Tributaries. Figures in bold italics were estimated, see text for methods.	33
4.	Retrospective performance of estimating Upper Yukon River Tributary escapement based on expansion of collective Sheenjek/Fishing Branch River escapement by 2.39 (= 1/0.417).	34
5.	Historical escapement of fall chum salmon in the Upper Yukon River mainstem. Figures in bold italics were estimated, see text for methods.	35
6.	Retrospective performance of estimating Total Upper Yukon River Escapement based on expansion of collective Sheenjek and Fishing Branch Rivers escapement by 3.19 (= 1/0.313).	36
7.	Fall chum salmon total utilization in numbers of fish, Yukon River drainage, District 1 – 3, 1961 - 1999. Figures in bold text were estimated.[a]	37
8.	Fall chum salmon total utilization in numbers of fish, Yukon River drainage, District 4 – 6, 1961-1999.[a]	38
9.	Fall chum salmon total utilization in numbers of fish, Alaskan and Canadian Areas of the Yukon River drainage, 1961-1999.	39
10.	Annual age composition estimates of the Yukon River fall chum salmon run, 1977–1999 at the mouth of the Yukon River	40
11.	Subsistence and personal use harvest of fall chum salmon, in District 5 and tributaries above the Tanana River, 1990 to 1995. Harvests are aggregated into areas, mainstem Yukon River below Tanana, mainstem Yukon River from Tanana to Porcupine River, mainstem Yukon River from the Porcupine River to the U.S./Canada border, and the Chandalar/Porcupine Rivers.	41
12.	Yukon River fall chum salmon total utilization aggregated by districts and areas within District 5 appropriate for stock specific run reconstruction, 1997-1999.	43
13.	Reconstructed Yukon fall chum salmon run by stock at the mouth of the Porcupine River, 1997-1999.	44
14.	Reconstructed Yukon fall chum salmon run by stock at the mouth of the Tanana River, 1974-1999.	45
15.	Reconstructed Yukon River fall chum salmon run by stock in at the mouth of the Yukon River, 1974-1999.	46
16.	Total run by age, (1974–1999) and total recruits by age, (1974–1995 brood years) for aggregate Yukon River fall chum salmon. Recruits estimated for incomplete broods, (1994–1995 brood years).	47

LIST OF TABLES (Continued)

Table **Page**

17. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Tanana River chum salmon. Recruits estimated for incomplete broods, (1994–1995 brood years)....48

18. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Upper Yukon River tributary fall chum salmon. Recruits estimated for incomplete broods, (1994 – 1995 brood years). 49

19. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Upper Yukon River mainstem fall chum salmon. Recruits estimated for incomplete broods, (1994 – 1995 brood years). 50

20. Stock-recruitment relationship statistics for Yukon River fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years. 51

21. Stock-recruitment relationship statistics for Tanana River fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years and for Ricker model fit to data from 1980 to 1995 brood years....52

22. Stock-recruitment relationship statistics for Upper Yukon River tributary fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years....53

23. Stock-recruitment relationship statistics for Upper Yukon River mainstem fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years....54

24. Tables of Markov transition probabilities for average yields over regular ranges of spawners. Tables presented for Yukon River and Tanana River fall chum salmon, based on spawner-recruit data for 1974 – 1995 brood years. 55

25. Tables of Markov transition probabilities for average yields over regular ranges of spawners. Tables presented for UpperYukon River tributary and Upper Yukon River mainstem fall chum salmon, based on spawner-recruit data for 1974 – 1995 brood years. 56

26. Portion of years when annual escapements for fall chum salmon stocks within the Yukon River were below, within, or above the biological escapement goal ranges recommended in this report. 57

LIST OF FIGURES

Figure		Page
1.	The Yukon Area showing communities and fishing districts, 2000.	58
2.	Top panel is estimated escapement, catch, and exploitation rate for the Yukon River fall chum salmon run, 1974 to 1999. Lower panel is estimated catch, escapement, and exploitation rate for Tanana River fall chum salmon, 1974 to 1999.	59
3.	Top panel is estimated escapement, catch, and exploitation rate for the Upper Yukon River tributary fall chum salmon run, 1974 to 1999. Lower panel is estimated catch, escapement, and exploitation rate for Upper Yukon River mainstem fall chum salmon, 1974 to 1999.	60
4.	Upper panel is auto-regressive Ricker stock recruitment relationship for Yukon River fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Yukon River fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).	61
5.	Residual plots for the Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.	62
6.	Return per spawner observed for a brood year versus the return per spawner observed for previous brood year. Labels for individual points are the brood year.	63
7.	Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.	64
8.	Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.	65
9.	Upper panel is Ricker stock recruitment relationship for Tanana River fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, solid line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Tanana River fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).	66
10.	Residual plots for the Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Tanana River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement	67
11.	Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Tanana River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.	68

Figure		Page
12.	Upper panel is auto-regressive Ricker stock recruitment relationship for UpperYukon River tributary fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Upper Yukon River tributary fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).	69
13.	Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Upper Yukon River tributary fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement	70
14.	Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Upper Yukon River tributary fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement	71
15.	Upper panel is auto-regressive Ricker stock recruitment relationship for UpperYukon River mainstem fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Upper Yukon River mainstem fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).	72
16.	Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Upper Yukon River mainstem fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.	73
17.	Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Upper Yukon River mainstem fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement	74
18.	Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for aggregate Yukon River fall chum salmon, and Upper Yukon River mainstem fall chum salmon.	75
19.	Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for Tanana River fall chum salmon, Toklat River fall chum salmon, and Delta River fall chum salmon.	76
20.	Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for Upper Yukon River tributary fall chum salmon, Sheenjek River fall chum salmon, and Fishing Branch River fall chum salmon	77

ABSTRACT

Available information was assembled concerning estimated escapements, harvests, and age composition of fall chum salmon *Oncorhynchus keta* returning to the Yukon River drainage in Alaska during the years 1974-1999. This information was used to reconstruct annual runs of fall chum salmon to the Tanana River, the Upper Yukon River tributaries (Chandalar, Fishing Branch, and Sheenjek Rivers), and the Upper Yukon River mainstem (the stocks enumerated at the U.S./Canada border and spawning upstream of the border). Brood tables consisting of estimated escapements and resultant age-specific recruits for the 1974 – 1995 brood years were developed for these stocks. These data were subsequently used to estimate spawner-recruit relationships based upon the estimated escapements of salmon to the Tanana River, Upper Yukon tributaries, and the Upper Yukon River mainstem during the years 1974-1995 and recruits resulting from these escapements 3, 4, 5 and 6 years later. These spawner-recruit relationships were used to estimate the number of spawners that would, on average, provide for maximum sustained yield of this stock of chum salmon in fisheries that are believed to harvest this stock. Based upon the spawner-recruit relationships developed in this report, it is recommended that the following biological escapement goals be formally adopted by the Alaska Department of Fish and Game.

Drainage-wide Yukon River fall chum salmon: 300,000 to 600,000 total spawners per year.

Tanana River fall chum salmon: 61,000 to 136,000 total spawners per year, as estimated by the sum of the Upper Tanana River escapement based on a mark-recapture project and the Toklat River survey counts.

Delta River fall chum salmon: 6,000 to 13,000 total spawners per year.

Toklat River fall chum salmon: 15,000 to 33,000 total spawners per year.

Upper Yukon River tributary fall chum salmon: 152,000 to 312,000 total spawners per year, as estimated by the sum of the Chandalar and Sheenjek River sonar counts and the Fishing Branch River Weir count.

Chandalar River fall chum salmon: 74,000 to 152,000 total spawners per year.

Sheenjek River fall chum salmon: 50,000 to 104,000 total spawners per year.

Fishing Branch River fall chum salmon: 27,000 to 56,000 total spawners per year. However, the U.S./Canada Joint Technical Committee (JTC) has set the BEG range at 50,000 – 120,000 fall chum salmon. Any changes to this BEG must be completed by the U.S./Canada JTC.

Upper Yukon River mainstem fall chum salmon: 60,000 to 129,000 total spawners per year. However, the U.S./Canada Joint Technical Committee (JTC) has set the BEG range at >80,000 fall chum salmon. Any changes to this BEG must be completed by the U.S./Canada JTC.

KEY WORDS: chum salmon, *Oncorhynchus keta,* Yukon River, commercial-related, brood table, biological escapement goal, maximum sustained yield, spawner-recruit relationship

INTRODUCTION

The Yukon River is the largest river in Alaska, draining approximately 35 percent of the state, and is the fifth largest drainage in North America. The river originates in British Columbia, Canada, within 30 miles of the Gulf of Alaska and flows over 2,300 miles to its mouth on the Bering Sea, draining an area of approximately 330,000 square miles. With the possible exception of a few fish taken near the mouth or adjacent coastal villages, only salmon of Yukon River origin are harvested in the Yukon River.

The chum salmon run to the Yukon River is made up of an early (summer chum salmon) and a late run (fall chum salmon). The summer chum salmon run is characterized by: early run timing (entry to the River occurs early-June to mid-July at the mouth), rapid maturation in freshwater, smaller size (average weight is 6-7 pounds), and larger population sizes. Summer chum salmon spawn primarily in the tributaries in the lower 500 miles of the Yukon River and in the Tanana River. The Yukon River fall chum salmon run is characterized by: late run timing (entry to the mouth occurs mid-July to early-September), robust body shape, larger size (average weight is 7-8 pounds) and smaller population sizes. Fall chum salmon spawn in the upper portion of the drainage in streams, which are spring-fed, usually remaining ice-free during the winter. Major fall chum salmon spawning areas include the Tanana, Chandalar, and Porcupine River systems, and various streams in the Yukon Territory, Canada, including the mainstem Yukon River. The Yukon summer and fall chum salmon runs are genetically distinct (Seeb and Crane 1999) and fisheries targeting these runs are managed separately.

Commercial salmon fishing occurs along the entire 1,200-mile length of the mainstem Yukon River in Alaska and the lower 225 miles of the Tanana River. The commercial fishing areas are divided into six districts and ten subdistricts for management and regulatory purposes (Figure 1). The present district boundaries were originally established in 1961 and redefined in 1962, 1974 1978, and 1996 (Bergstrom et al. 1999). The Coastal District was established in 1994 and is only opened to subsistence fishing. The Lower Yukon Area (Districts 1, 2 and 3) includes coastal waters of the delta and that portion of the Yukon River drainage from the mouth to Old Paradise Village, river mile 301. The Upper Yukon Area (Districts 4, 5 and 6) includes that portion of the drainage upstream from Old Paradise Village to the U.S./Canada border.

The first recorded commercial salmon harvests in the Yukon River occurred in 1918. Relatively large harvests of Yukon River fall chum salmon occurred from 1919 to1921. The early commercial fisheries in the Yukon River were controversial due to the large subsistence utilization. Commercial fisheries were restricted after 1925, although sporadic harvest of fall chum salmon occurred in the Yukon River prior to statehood (Bergstrom et al. 1999). The commercial fishery for fall chum salmon was established in 1961. Commercial harvests of Yukon River fall chum salmon increased during the late-1970s due to the increased efficiency of commercial fishermen and above average runs. Commercial salmon harvests have declined since the late-1980s because of commercial fishery restrictions imposed in response to concerns for possible over-fishing and lower than average runs.

Subsistence fishing occurs throughout most of the Yukon Area. Historically, subsistence salmon harvests were very large and continued to be a large portion of the utilization after the establishment of commercial fisheries.

The Alaska Department of Fish and Game (ADF&G) has managed the fall chum salmon fisheries in the Yukon River over the past few decades with the dual goal of maintaining important fisheries while at the same time achieving desired escapements. Escapement objectives for five Yukon River fall chum salmon populations have been in effect over the past 20 years. Long term monitoring of Yukon River fall chum salmon escapements occur in the Toklat River (aerial and foot survey counts expanded based on stream residence time estimated for the Delta River), the Delta River (aerial and foot survey counts expanded based on stream residence), the Sheenjek River (aerial survey and sonar count), the Fishing Branch River (aerial survey and weir count), and in the mainstem Yukon River at the U.S./Canada Border (estimate of passage at the border less upstream harvests based on annual Canadian Department of Fisheries and Oceans (DFO) mark-recapture project). Escapement goals currently exist for these five components of the Yukon fall chum salmon run.

Buklis (1993) provides the following narrative concerning the historical background for the various escapement goals that ADF&G used for the Yukon River fall chum salmon stocks through the year 1992:

Toklat River

> *"A fall chum salmon escapement goal of 40,000 aerial survey counts was proposed for the Toklat River in 1979. In 1981, a range of 30,500 to 75,000 was proposed. In April 1982, a goal of 40,000 was proposed for the upper Toklat River index area. In 1984, a goal of 69,000 for the perceived high abundance cycle years (1971, 1975, 1979, etc), and a goal of 22,000 for low abundance years was established for the index area (ADF&G 1984). The goal was revised to 44,000 for all years in the cycle in November 1985, and was a population goal based on expanded aerial survey counts (ADF&G 1985). A comprehensive review of escapement data for the Toklat River was made in November 1986. A revised population escapement goal of 33, 000 was established based upon a trimmed average of escapements for 1974-1985, excluding the two high and two low years."*

Delta River

> *"A fall chum escapement goal of 7,000 aerial survey counts was proposed for the Delta River in 1979. In 1981, an aerial survey escapement goal range of 4,500 to 11,000 was proposed. In April 1982, a goal of 8,000 was proposed. In April 1984, an escapement goal of 7,900 was established for the Delta River (ADF&G 1984). In 1985, a goal of 15,800 was established, and was a population goal based upon expanded aerial survey counts (ADF&G 1985). A comprehensive review of escapement data for the Delta River was made in November 1986. A revised population escapement goal of 11,000 was established based upon a trimmed average of escapements for 1974-1986, excluding the two high and two low years."*

Sheenjek River

> *"A fall chum salmon escapement goal of 20,000 aerial survey counts was proposed for the Sheenjek River in 1979. In 1981, a range of 15,000 to 53,000 was proposed. In April 1982, a goal of 40,000 was proposed. In 1984, a goal of 60,000 fall chums for the perceived high abundance cycle years (1971, 1975, 1979, etc), and 19,000 for low abundance years was established (ADF&G 1984). The goal was revised to 40,500 for all years in the cycle in November 1985, and was a population goal based upon sonar or expanded aerial survey counts (ADF&G 1985). A comprehensive review of escapement data for the Sheenjek River was made in November 1986. A revised population escapement goal of 62,000 was established based upon a trimmed average of escapements for 1974-1985, excluding the two high and two low years. In 1992 the escapement goal was revised to 64,000 based on trimmed average of escapements 1974-1990."*

Fishing Branch River (Canada).

"A fall chum escapement goal range of 20,300 to 61,300 aerial survey counts was developed by ADF&G in April 1981 for the Fishing Branch River. In April 1982 an aerial survey goal of 60,000 was developed. In 1984, a goal of 61,000 fall chums for the perceived high abundance cycle years (1971, 1974, 1979 etc.), and 17,000 for low abundance years was developed. Since this was a spawning stock in Canada, these goals were not formally established in that they were not listed in fishery management plans or annual management reports for the Yukon River in Alaska. In 1987, an escapement goal range of 50,000 – 120,000 weir counts was established. This escapement goal range was established by the U.S./Canada Joint Technical Committee (JTC) (U.S./Canada JTC, 1987) and was based on an inspection of Fishing Branch River fall chum salmon escapements from 1974 – 1986, and mixed stock fishery harvests (not attributed specifically to the Fishing Branch River stock) lagged four years later."

Mainstem Yukon River (Canada).

"The U.S./Canada JTC established a mainstem Canadian Yukon River interim fall chum salmon escapement goal range of 90,000 to 135,000 in 1987 (U.S./Canada JTC, 1987). Escapement is determined by the annual DFO tagging study. That interim goal was reviewed and revised by the JTC in November 1990 and changed to an escapement >80,000 1987 (U.S./Canada JTC, 1990)."

Buklis (1993) and ADF&G (1992) reported that the escapement goals established for the Toklat, and Delta Rivers in 1986 and the Sheenjek River goal in 1992 were considered minimum escapement goals starting with the 1992 fishing season.

In 1999, interim revised biological escapement goal ranges were developed for the Delta, Toklat and Sheenjek Rivers (Barton 1999). An escapement goal range of 8,000 to 17,000 was recommended for the Delta River, based on 0.8 to 1.6 of the median escapement for the years 1972 – 1998. An escapement goal range of 22,000 to 45,000 was recommended for the Toklat River. The goal was based on 0.8 to 1.6 of the median escapement for years 1974 – 1998 [note that, a year when a foot survey was not conducted (1977) and the years of low escapements, (i.e., escapements less than 15,000 for 1982, 1988, 1991, 1992 and 1997) were excluded]. An escapement goal range of 66,000 to 132,000 was recommended for the Sheenjek River. The goal was based on 0.8 to 1.6 of the median escapement for the years 1974 – 1998 (note that 1978 was excluded because aerial survey conditions were poor).

This report is written to document the reconstruction of the total Yukon River fall chum salmon runs (stock specific catch and escapement) for the years 1974 – 1999, by age, for the following stocks: (1) Tanana River (historical escapement indexed by expanded Toklat and Delta River foot survey counts), (2) Upper Yukon tributaries (historical escapement indexed by the Sheenjek River sonar and Fishing Branch River weir counts), and (3) Upper Yukon mainstem (escapement estimated based on DFO mark-recapture project). With the establishment of the Chandalar River sonar project and the Upper Tanana River mark-recapture projects in 1995, there is a complete assessment of the total stock specific runs of fall chum salmon to the Yukon River. The historical run reconstructions were based in part on expansion factors for historical index escapement counts to total escapement, estimated from average ratio of total escapement to index escapement for the years since 1995. The stock specific run reconstruction will enable an assessment of recruits from parent escapements for the 1974 – 1995 brood years. In addition, the report will document current analyses relevant to developing stock-recruit relationships for the aggregated Yukon River fall chum salmon stock and three Yukon River fall chum salmon stocks within the Yukon River drainage. The report will also provide documentation of and recommendations to ADF&G as to the appropriate biological escapement goals for five escapement indicator populations.

YUKON RIVER FALL CHUM SALMON ESCAPEMENTS, HARVESTS, AND RUNS

Yukon River Fall Chum Salmon Escapements

Tanana River Escapement

The escapement of fall chum salmon in the Tanana River drainage (Table 1) has been monitored in two tributary systems, the Delta River (1974 to present), and the Toklat River (1974 to present). Passage to the Upper Tanana River drainage above the Kantishna River has been monitored by a mark-recapture project (1995 to present). Toklat River escapements were based on expanded ground or aerial survey counts made at Toklat Springs using streamlife and migratory time density data collected from Delta River fall chum salmon surveys (Barton 1997). The Toklat River survey counts are a very conservative estimate of the fall chum salmon escapement to the Kantishna River drainage. The Toklat River is a tributary of the Kantishna River, and a significant population of fall chum salmon is known to spawn in the Kantishna River above the Toklat River. Limited monitoring of the Kantishna River escapement occurred in 1999 and 2000 with an extension of an existing mark-recapture project. For those years, the estimated Kantishna River (including the Toklat River) fall chum salmon escapement above the Toklat River was 4 to 5 times the Toklat River survey counts (Pete Cleary, ADF&G, 1300 College Road, Fairbanks, AK 99701, personal communication). However, there are insufficient years of paired data (i.e., paired Toklat River survey counts and Kantishna River mark-recapture estimates) over a range of Toklat River escapements to develop a method to expand the historical Toklat River survey counts to the entire Kantishna River drainage.

The Delta River escapements were based on peak aerial survey counts in 1974 and foot survey counts, 1975 to present. The peak aerial survey count was expanded by 1.475 based on a comparison of replicate foot and aerial surveys conducted in 1985 (Barton 1986). Delta River foot survey counts were expanded based on spawner abundance curves and estimates of stream life (Barton 1986). Estimates of total passage to the Upper Tanana River are based on mark-recapture projects (Cappiello and Bromaghin 1995, Cappiello and Bruden 1997, Hebert and Bruden 1998, Cleary and Bruden 2000). For the years 1995 – 1999, paired estimates of Upper Tanana River passage and Delta River escapements indicate that the Delta River escapements averaged 12.3% of the Upper Tanana River passage. For these years, a retrospective estimate of Upper Tanana River escapement based on expansion of the Delta River survey counts had a mean absolute percent error (MAPE) of 20% and a mean absolute error (MAE) of 28.3 thousand (Table 2). Estimates of Upper Tanana River escapements, 1974 – 1994, were based on an expansion of the respective year Delta River foot survey counts by 8.13 (Table 1). Escapements to the Tanana River drainage were considered to be the sum of the escapement to the Toklat and the Upper Tanana Rivers (Table 1).

Upper Yukon River Tributaries Escapement

The spawning of fall chum salmon in the Upper Yukon River, above the confluence of the Tanana River to the U.S./Canada border, is thought to occur in the Chandalar and Porcupine Rivers. These spawning populations are hereafter referred to as the Upper Yukon River Tributaries. Fall chum salmon escapement has been monitored in the Upper Yukon River Tributaries (Table 3) in the Sheenjek River (1974 to present), in the Fishing Branch River (1974 to present), and in the Chandalar River (1995 to present). The Sheenjek and Fishing Branch Rivers are the two principal spawning areas for fall chum salmon in the Porcupine River drainage.

The Sheenjek River escapements were based on aerial survey counts (1974 – 1980) and non-user configurable sonar counts (1981 to present), (Barton 1995). Aerial survey counts were expanded by 2.92 based on simultaneous sonar and aerial survey counts that were conducted in 1993 (Barton 1999a). From

1981 to 1990 the Sheenjek sonar project was initiated relatively late in the run, around August 25. After 1991, the project was initiated earlier, around August 8. The early year sonar counts were expanded for the portion of the run that was not counted derived from estimated average run timing curves based on years where non-user configurable sonar was operated on the Chandalar (1986 – 1990) and Sheenjek Rivers (1991 – – 1993) (Barton 1999a).

The Fishing Branch River escapements were based on aerial survey counts (1976 – 1984) and weir counts (1974 – 1975, and 1985 to present). The aerial survey counts were expanded by a factor of 2.72. The expansion factor developed by the JTC was presumably based on analysis of simultaneous aerial survey and weir counts.

The Chandalar River escapements were based on user configurable sonar counts, 1995 to present (Daum and Osborn 1996, 1998a, 1998b and 2000). Note that non-configurable sonar was operated on the Chandalar River, from 1986 – 1990, however those counts were not considered a complete assessment because of limited ensonification of the River cross-section achieved with the non-configurable system. The total fall chum salmon escapement to the Upper Yukon River Tributaries was assessed, for years 1995 – 1999. The escapement to the Chandalar River was closely related to the collective escapement of the Sheenjek and Fishing Branch Rivers (Table 4). A linear regression model was fit ($Y = 1.86\ X$, $R^2 = 0.88$, $p = 0.012$) to the paired observations. For these years, a retrospective estimate of Upper Yukon River Tributary fall chum salmon escapement based on expansion (1.86) of the collective Sheenjek and Fishing Branch River escapements had a MAPE of 48.3% and MAE of 61.5 thousand (Table 4). Estimates of Upper Yukon River Tributary escapements, 1974 – 1994, were based on expansion of the respective year collective Sheenjek sonar and Fishing Branch weir counts by 1.86 (Table 3).

Upper Yukon River Mainstem Escapement

The Department of Fisheries and Oceans (DFO) have monitored the passage (escapement plus catch in Canadian fisheries in the Yukon River above the border) of fall chum salmon at the U.S./Canada border in an annual mark-recapture project. Estimates of escapement for the Upper Yukon River mainstem (border passage less upstream Canadian harvests) have been made from 1980 to the present (Table 5).

The estimates of the Upper Yukon River mainstem escapements for years 1974 – 1979 were based on expansion of the collective Sheenjek and Fishing Branch River escapements to the Upper Yukon River and subtraction of the estimated Upper Yukon River Tributary escapement (Table 5). The escapement of the Upper Yukon River (i.e., the sum of the Upper Yukon River Tributary escapement and the Upper Yukon mainstem escapement) was closely related to the collective escapement of the Sheenjek and Fishing Branch Rivers (Table 6). A linear regression model was fit ($Y = 2.31\ X$, $R^2 = 0.89$, $p < 0.001$) to the paired observations. For the years 1980-1999, the Upper Yukon River escapement was 2.31 times the collective escapement of the Sheenjek and Fishing Branch Rivers. For these years, a retrospective estimate of Upper Yukon River fall chum salmon escapement based on the regression expansion of the collective Sheenjek and Fishing Branch Rivers has a MAPE of 13.4% and MAE of 38 thousand (Table 6).

Yukon River Fall Chum Salmon Harvests

Total utilization of Yukon River fall chum salmon includes commercial harvests, commercial-related harvests, subsistence, personal use, and ADF&G test fishery harvests (Tables 7-9). Commercial harvests are estimated from fish tickets. Commercial-related harvests are the estimated number of carcasses made available for subsistence use, after the sale of the roe. There is a potential for commercial-related harvests to be reflected both in the fish tickets and in the subsistence surveys. To avoid the double counting, commercial-related harvests are monitored separately and estimated from a combination of fish ticket sales and subsistence survey program results. Currently only one non-subsistence area is designated within the Yukon River drainage and largely encompasses the section of the Tanana River near Fairbanks. Subsistence fishing permits are required primarily in areas that have road access and include the entire Tanana River drainage and sections of the Upper Yukon River (Holder and Hamner 1995, 1998a, 1998b; Borba and Hamner 1996, 1997, 1998, 1999, 2000). Subsistence surveys prior to 1979 were conducted prior to the end of the fall chum salmon run, and therefore the subsistence survey based harvest estimates of fall chum salmon were negatively biased. Subsistence harvests in all districts were stable during the decade after initiation of full subsistence surveys. To correct for the under reporting of subsistence harvests prior to 1979, subsistence harvests in Districts 1 – 6, for the years 1974 – 1978, were estimated based on the average subsistence harvest in the respective districts, 1979 – 1986 (Table 7 - 8).

Age Composition of Annual Escapements and Runs

The annual age compositions of the aggregate Yukon River fall chum salmon runs were based on annual estimates of age composition provided from sampling in the lower Yukon River (Barton, 1999b). For years 1977 – 1980, the ages were estimated from the District 1 commercial 6-inch mesh gill net catch samples (Table 10). For subsequent years, age compositions were estimated from sampling the 6-inch mesh gillnets in the ADF&G test fishery at the Big Eddy and Middle Mouth sites. Corrections were made for years when the test fishery was not completely sampled. In the initial years of the test fishery, 1981 – 1982, samples from the commercial fishery gill net harvests were used during blocks of time for which no test fishery age samples were available. In 1994, the lower river test fishing operations were terminated prior to the conclusion of the season's run. Therefore, estimates of age composition were based on extending the relative abundance of specific ages in the initial test fishery samples based on mean age specific run timing curves estimated from test fisheries in prior years.

Reconstructed Total Runs of Yukon Fall Chum Salmon

General Model of Yukon River Fall Chum Salmon Runs

The estimated total annual run size of Yukon River fall chum salmon includes the total utilization in Alaskan and Canadian fisheries plus the estimated escapement to the Tanana River, the Upper Yukon River tributaries (i.e., the Chandalar, Sheenjek, and Fishing Branch Rivers) and the Upper Yukon River mainstem escapement at the U.S./Canada border. This model is conservative to the extent that spawning populations of fall chum salmon may occur in the mainstem Yukon River downstream of the U.S./Canada border and in tributaries where escapement is not assessed. Limited escapement estimates are available for other populations, and significant populations of fall chum salmon may occur in the Kantishna River above the Toklat River and in the Koyukuk Rivers. Estimates of escapement to the Kantishna River which including the Toklat River were 21.1 and 27.3 thousand in 1999, and 2000, respectively. These estimates were substantially greater than the expanded Toklat River survey counts and may indicate a significant spawning in the Kantishna River drainage outside the Toklat River. Estimates of escapement in the South Fork of the Koyukuk River were 19.5, 21.7, and 16.4 thousand in 1990, 1996 and 1997, respectively.

Independent assessments of Yukon River fall chum salmon runs are available from the Rampart mark-recapture project, 1996 – 1999 (Gordon et al. 1998; Underwood et al. 2000). To reconstruct the Yukon River fall chum salmon run at Rampart requires partitioning the District 5 utilization into that taken above and below Rampart. The subsistence and personal use harvests have been apportioned to areas within District 5 based on the distribution of harvests within District 5 from subsistence surveys and returned subsistence permits (Table 11). Subsistence users from the villages of Tanana and Rampart generally fish in the Yukon River below the Rampart area, and all other users in District 5 fish above the Rampart area. The proportion of the District-5 subsistence and personal use harvests taken by residents of Tanana and Rampart was 47.9%, 46.5%, 79.8% and 49.7% for the years 1996 – 1999, respectively. These percentages were used to estimate District 5 total utilization below and above Rampart for the respective years. The reconstructed run at Rampart was the sum of the District 5 utilization above Rampart, the Canadian utilization, the Upper Yukon River Tributary escapement, and the Upper Yukon River mainstem escapement.

Year	Estimated Passage at Rampart	Reconstructed Run at Rampart	District 5 Utilization Above Rampart	Canadian Utilization	Escapement Above Rampart	Percent Error
1996	654,296	723,611	44,491	24,354	654,766	-10.6%
1997	369,546	439,926	31,651	15,580	392,695	-19.0%
1998	194,963	182,663	6,337	7,904	168,422	6.3%
1999	189,742	228,216	26,951	19,574	181,691	-20.3%
				Average Percent Error		-10.9%

The Upper Yukon River runs reconstructed at Rampart averaged about 11% greater than the passage at Rampart, as estimated from the Rampart mark-recapture project. The differences in reconstructed runs and estimates of passage at Rampart were within expectations based on measurement errors inherent in the assessment methods and do not indicate that any significant spawning populations of fall chum salmon above Rampart are being excluded.

Independent assessments of Yukon fall chum salmon runs are also available at the Pilot Station sonar site (1995, 1997 - 1999). The above model of Yukon River fall chum salmon runs was tested by comparing the reconstructed run at Pilot Station and the estimated passage by the Pilot Station sonar. The run at Pilot Station was reconstructed using the assumption that about half of the Y-2 district utilization occurs below Pilot Station (D.J. Bergstrom, Alaska Dept. of Fish and Game, Anchorage, AK; personal communication). The reconstructed run of fall chum salmon at Pilot Station was the sum of one half the District 2 utilization, Districts 3-6 utilization, Canadian utilization, and escapement.

Year	Passage at Pilot Station	Reconstructed Total Run at Pilot Station	Total Utilization above Pilot Station	Escapement	Percent Error
1995	1,070,968	1,431,586	375,983	1,055,603	-33.7%
1997	521,531	617,444	138,577	478,867	-18.4%
1998	353,371	314,021	67,610	246,411	11.1%
1999	405,230	404,587	113,476	291,111	0.2%
			Average Percent Error		-10.2%

The reconstructed runs at Pilot Station averaged about 10% greater than the Pilot Station sonar count. This observation seems to be inconsistent with the occurrence of a significant unmonitored spawning population in the Kantishna and Koyukuk Rivers and may indicate that the Pilot Station sonar counts are biased low, particularly in situations of counting large runs past the sonar.

Stock Identification of Harvests

There is little specific information regarding the stock composition of Yukon fall chum salmon utilizations. In the following, utilizations were apportioned to stock based on assumptions of precise homing and similar run timing among the three stocks of Yukon River fall chum salmon. Radio telemetry studies, conducted in 1998-1999 of radio tagged fish released at Rampart, (Underwood et al.

2000) were to test the hypothesis of no differences in run timing among the Upper Yukon River tributary and Upper Yukon River mainstem stocks. The relative proportion of these stocks in the passage at Rampart by week was estimated for 1998 and 1999 based on distribution of radio tagged fall chum salmon observed spawning areas (John Eiler, NMFS Auke Bay Laboratory, Juneau, personal communication). The relative proportion of recoveries aggregated by stock, by week is provided in the following table. In 1998 there were no differences in the stock's relative distribution over time (2 x 4 chi square test, $p = 0.13$). In 1999 there were differences in distribution in the stock's relative distribution over time (3 x 7 chi square test, $p > 0.01$); however, these differences were due to a relatively high contribution of U.S. mainstem fish in week 32, and relatively high contribution Upper Yukon mainstem in week 39. There was no difference in the distribution of the stock in weeks 33- 38 (3 x 5 chi square test, $p = 0.41$).

1998 Data

		Distribution of Radio Tags in Escapement					
		U.S. Mainstem below Fort Yukon		Chandalar/Porcupine River		Upper Yukon Mainstem	
Week	Abundance	No. of Tags	Percent	No. of Tags	Percent	No. of Tags	Percent
32							
33							
34							
35	31,496	---	---	36	13.7%	14	19.4%
36	42,504	---	---	53	20.2%	8	11.1%
37	58,635	---	---	102	38.8%	24	33.3%
38	37,931	---	---	72	27.4%	26	36.1%
39							

1999 Data

		Distribution of Radio Tags in Escapement					
		U.S. Mainstem below Fort Yukon		Chandalar/Porcupine River		Upper Yukon River Mainstem	
Week	Abundance	No. of Tags	Percent	No. of Tags	Percent	No. of Tags	Percent
32	8,127	12	36.4%	15	4.3%	2	2.7%
33	54,449	2	3.0%	46	13.1%	6	8.2%
34	26,439	1	0.9%	75	21.4%	13	17.8%
35	28,411	1	0.9%	75	21.4%	16	21.9%
36	12,851	1	1.6%	35	10.0%	12	16.4%
37	25,104	0	0.0%	50	14.3%	11	15.1%
38	19,386	0	0.0%	42	12.0%	4	5.5%
39	14,974	1	2.4%	12	3.4%	9	12.3%

The available radio telemetry data suggest minor differences in run timing among Yukon River fall chum salmon. Based on assumptions of precise homing and similar run timing among the three stocks of Yukon River fall chum salmon, the Yukon River fall chum salmon harvests can be partitioned by stock in several areas that would be expected to have similar stock composition:

1. Areas where the Tanana River, Upper Yukon River tributary, and the Upper Yukon River mainstem stocks have similar vulnerability include the areas downstream of the Tanana River, these areas are designated Districts 1-4, and the portion of District 5 downstream of the Tanana River confluence.

The annual utilization in these areas was separated into stock specific utilization based on the relative magnitude of the three stocks' respective year's run upstream of the mouth of the Tanana River.

2. District 6 utilization was assumed to be entirely of Tanana River origin.

3. Areas where the Upper Yukon River tributary stock and the Upper Yukon River mainstem stocks have similar vulnerabilities include the portion of District 5 between the Tanana River and the Porcupine River. The annual utilization in this area was separated into stock specific utilization based on the two stock's respective year run upstream of the Porcupine/Chandalar Rivers.

4. Utilization in the Chandalar and Porcupine Rivers was assumed to be entirely of Upper Yukon River Tributary origin.

5. Utilization upstream of the Porcupine River was assumed to be entirely of Upper Yukon River mainstem origin.

District 5 utilizations were apportioned to the following areas appropriate for stock identification: areas downstream of the Tanana River, Yukon mainstem between the Tanana River and the Porcupine/Chandalar Rivers, areas in the Chandalar and Porcupine Rivers, and areas upstream of the Porcupine River (Table 12). Apportionment of the District 5 utilizations were based on the respective subsistence and personal use harvests in these areas estimated from subsistence surveys and returned fishing permits (Table 11). Here the utilization in District 5 below the Tanana River were in proportion to the Tanana Village utilization; in District 5 between the Tanana River and the Porcupine/Chandalar Rivers were in proportion to the in proportion to the sum of Rampart Village, Fairbanks subsistence/personal use, Stevens Village, Beaver Village, and one half of Fort Yukon utilizations; In District 5 above the Porcupine/Chandalar Rivers were in proportion to one half Fort Yukon, Central, Circle, Eagle and other Villages (Table 11). The utilization in District 5 that occurred in the Porcupine/Chandalar River was in proportion to the sum of the Venetie and Chalkyitsik Village utilizations. For the years 1990 – 1999, the respective year subsistence and personal use harvests by area within District 5, were used to partition the District 5 utilization (Table 11). For the years 1974 - 1989, the average distribution of subsistence and personal use harvests within District 5 for the years 1990 – 1999, was used to partition the District 5 utilization (Table 12).

Yukon River fall chum salmon runs were reconstructed in stages beginning with the upper river runs and then sequentially reconstructing the runs downriver. The run at the mouth of the Chandalar and Porcupine Rivers was constructed first, followed by the run at the mouth of the Tanana River, and completed by the run at the mouth of the Yukon River.

The run in the Yukon River at the mouth of the Chandalar and Porcupine Rivers can be apportioned into the Upper Yukon River tributary and Upper Yukon River mainstem stocks. The harvests and escapements within the Chandalar and Porcupine River drainages were assumed to be specific to the Upper Yukon River tributary stock. The run of Upper Yukon River tributary stock was considered the escapement and utilization in the Chandalar and Porcupine River drainages. The run of Upper Yukon River mainstem stock was considered to be the harvests in the Yukon River mainstem above the mouth of the Porcupine River, Canadian harvests in the Yukon River mainstem, and escapement at the U.S./Canada border (Table 13).

The Yukon River fall chum salmon run at the mouth of the Tanana River consists of the run downstream from mouth of the Chandalar and Porcupine Rivers, including the utilization in the mainstem Yukon River to the Tanana River, and the run in the Tanana River drainage. The relative magnitude of the Upper Yukon River tributary and Upper Yukon River mainstem runs at the Chandalar and Porcupine

Rivers (Table 13) was used to apportion the utilization in District 5 from the Tanana to Chandalar and Porcupine Rivers. District 6 utilization and the Tanana River escapements were assumed to be specific to the Tanana River stock. Reconstruction of the Yukon River fall chum salmon run at the mouth of the Tanana River is provided in Table 14.

The Yukon River fall chum salmon run at the mouth of the Yukon River consists of the run downstream of the confluence of the Tanana River (which necessitates an inclusion of a portion of what is designated District 5) plus the utilization in Districts 1-4. The relative magnitude of the Tanana River, Upper Yukon River tributary and Upper Yukon River mainstem runs at the mouth of the Tanana River (Table 14) was used to apportion the utilization in Districts 1-4 and that portion of District 5 downstream of the Tanana River (Table 12). Reconstruction of the fall chum salmon run at the mouth of the Yukon River is provided in Table 15.

The reconstructed total fall chum salmon run by age for the years 1974 – 1999 was estimated by applying the annual estimates of age composition (Table 10) to the reconstructed runs at the mouth of the Yukon River (Table 15).

Estimation of Recruits from Parent Escapement by Age

The recruits, by age, from parent escapements were estimated for the 1974 - 1995 brood years. The recruits from brood year y and age a is the escapement and utilization for age a in calendar year y + a.

$$\hat{R}_{a,y} = \hat{E}_{a,y+a} + \hat{U}_{a,y+a} \tag{1}$$

$R_{a,y}$ is the recruits for age a and brood year y, $E_{a,y+a}$ is the escapement by age a and calendar year y+a, and $U_{a,y+a}$ is utilization by age a and calendar year y+a.

Production for year classes 1974 through 1995 was estimated for each cohort as the sum of production at age over ages of the cohort:

$$\hat{R}_y = \sum_{a=3}^{6} \hat{R}_{a,y} \tag{2}$$

For the 1994 and 1995 brood years, production was incomplete and estimated by summing across younger ages, then prorating these sums for the older ages yet to mature:

$$\hat{R}_{1992} = \frac{\sum_{a=3}^{5} \hat{R}_{a,1994}}{1-\hat{\bar{\tau}}_6} \qquad \hat{R}_{1993} = \frac{\sum_{a=3}^{4} \hat{R}_{a,1993}}{1-\hat{\bar{\tau}}_{5+}} \tag{3}$$

Where: $\hat{\bar{\tau}}_6$ is the average fraction of production represented by six-year-olds for year classes 1974 through 1993, $\hat{\bar{\tau}}_{5+}$ the average fraction for five-year-olds and older for year classes 1974 through 1993.

The total runs by age for 1974 – 1999 and recruits by age for the 1974 – 1995 brood years for the aggregate Yukon River fall chum salmon, Tanana River, Upper Yukon River tributary, and Upper Yukon River mainstem fall chum salmon are presented in Tables 16 – 19, respectively. Plots of total run and exploitation rate for years 1974 – 1999 by stock are provided in Figures 2 and 3.

SPAWNER-RECRUIT RELATIONSHIPS FOR YUKON RIVER ORIGIN FALL CHUM SALMON

Methods

Spawner-recruit relationships were developed by fitting paired observations of recruits and escapement to the following model:

$$R_y = \alpha S_y e^{-\beta S_y} \exp(\varepsilon_y) \tag{4}$$

where: R_y = estimated total recruitment by brood y;
S_y = spawning escapement that produced brood y;
α = intrinsic rate of population increase in the absence of density-dependent limitations;
β = density-dependent parameter; and
ε_y = process error with mean 0 and variance σ^2_ε.

This model, commonly referred to as a Ricker recruitment curve (Ricker 1975), has two parameters, α and β, to estimate, given a series of spawner and resultant recruitment observations or estimates. I assumed the errors were log-normal (as is common for salmon returns), resulting in the log-transformed linear equation:

$$\ln(R_y/S_y) = \ln(\alpha) - \beta S_y + \varepsilon_y \tag{5}$$

Linear regression procedures provided estimates of the intercept (ln α) and the slope (β) in equation 2. Hilborn and Walters (1992:271-2) published the following empirical approximation of the estimated spawning size that produces maximum sustained yield or MSY (S_{MSY}) as a function of estimated parameters:

$$\hat{S}_{MSY} \cong \frac{\widehat{\ln\alpha} + \hat{\sigma}^2_\varepsilon/2}{\hat{\beta}}[0.5 - 0.07(\widehat{\ln\alpha} + \hat{\sigma}^2_\varepsilon/2)] \tag{6}$$

where: $\hat{\sigma}^2_\varepsilon$ = the mean square error from the regression.

The estimated variance $v(\hat{S}_{MSY})$ and 90% confidence intervals for $\hat{S}_{MSY}$ were calculated through non-parametric bootstrapping of residuals from the regression (see Efron and Tibshirani 1993:111-5). Residuals were calculated as differences between observed and predicted values:

$$\zeta_y = Y_y - \hat{\mathrm{E}}[Y_y] \tag{7}$$

where: ζ_y = the residual for brood y;
Y_y = $\ln(R_y/S_y)$;
$\hat{\mathrm{E}}[Y_y]$ = the predicted value.

A new set of dependent variables were generated by sampling the residuals from the original regression:

$$\widetilde{Y}_y = \zeta_y^* + \hat{E}[Y_y] \tag{8}$$

where the ζ_y^* were drawn randomly with replacement from the original vector of the n original residuals $\{\zeta_y\}$ (n = the number of brood years in the analysis). In this fashion a new data set was created comprised of the original values for the independent variables (spawning abundance, either total or female only) and corresponding simulated values $\widetilde{Y}_y$. The $\widetilde{Y}_y$ were then regressed against the original values of the independent variables to produce a new, simulated set of parameter estimates for ln α, β, and σ_ε^2. These new parameter estimates were plugged into equation 6 to produce a simulated estimate $\widetilde{S}_{MSY}$. This process was repeated 1,000 times to produce 1,000 simulated estimates of $\widetilde{S}_{MSY}$. From Efron and Tibshirani (1993:47):

$$v(\hat{S}_{MSY}) = \frac{\sum_{b=1}^{1000} (\widetilde{S}_{MSY(b)} - \overline{S}_{MSY})^2}{1000 - 1} \tag{9}$$

where $\overline{S}_{MSY} = 1000^{-1} \sum_{b=1}^{1000} \widetilde{S}_{MSY(b)}$. Ninety percent confidence intervals about $\hat{S}_{MSY}$ were estimated from the 1,000 simulations with the percentile method (Efron and Tibshirani 1993:124-126). The 1,000 values of $\widetilde{S}_{MSY}$ for each scenario were sorted in ascending order making the 51st and the 950th values the lower and upper bounds of a 90% confidence interval.

In some of the analyses residuals from the fit of the standard Ricker model were significantly auto-correlated at a lag of one generation. The dampened oscillation in the auto-correlation function beyond that lag and the lack of significance in the partial autocorrelation function indicated an auto-regressive process. Using the methods described in (Noakes et al. 1987) and Pankratz (1992), Ricker's linearized production model was modified to include an auto-regressive parameter ϕ_1:

$$\ln(R_y/S_y) = \ln(\alpha) - \beta S_y + a_y(1 - \phi_1 \mathrm{B})^{-1} \tag{10}$$

where B is a "back-shift" operator (when used, describes a value of a variable from the previous generation). Multiplying both sides of the equation by 1 - ϕ_1B and simplifying:

$$\ln(R_y/S_y) = (1 - \phi_1)\ln(\alpha) + \phi_1 \ln(R_{y-1}/S_{y-1}) - \beta(S_y - \phi_1 S_{y-1}) + \varepsilon_y \tag{11}$$

provides an auto-regressive model with estimable parameters. Parameters were estimated by method of maximum likelihood. Because it is involved solely in the error term in equation 12, ϕ_1 is a nuisance parameter, and therefore drops out of the first derivative of this equation. The equation to estimate S_{MSY} from the auto-regressive form of Ricker's model is the same as that derived for the standard model (Equation 6):

$$1 = (1 - \hat{\beta}\hat{S}_{MSY}) \exp(\widehat{\ln \alpha}) \exp(-\hat{\beta}\hat{S}_{MSY}) \exp(\hat{\sigma}_\varepsilon^2/2) \tag{12}$$

The initial estimate of S_{MSY} as used as the point value for recommending a biological escapement goal and this biological escapement goal is expressed as a range. The range is estimated as the range of escapements that produce 90% or greater of maximum sustained yield.

Spawner-Recruit Relationship and Biological Escapement Goals.

The 1975 reconstructed Yukon River fall chum salmon run was very unusual (Figure 2). The magnitude of the reconstructed run was 1.938 million, the largest in the 26-year time series, and approximately 1.4 times the next largest run of 1.396 million that occurred in 1979. The total utilization for 1975 was 339 thousand, which was large but not excessive as four years in the series had a larger utilization. The large run estimated for 1975 was due almost entirely to the large escapement (354 thousand) observed in the Fishing Branch River (Table 3). This escapement level was very unusual. The escapement was the largest in the 26-year time series, almost three times the next largest Fishing Branch River escapement observed in 1979. The probability of such a large escapement, based on the normal frequency distribution and log-normal frequency distribution fit to the Fishing Branch River escapement data, is 2.83×10^{-6} and 0.0013, respectively. Such an escapement level is extreme by any statistical criteria, and the recruits estimated from the escapement level would have a very large influence on the spawner recruit relationship and MSY escapement levels estimated from the data. Because of the lack of escapement data, other than the four stocks that were monitored in 1975, the Fishing Branch River escapement expands to a very large escapement for the Upper Yukon River tributaries and Upper Yukon River mainstem stocks. The assessment of Yukon River fall chum salmon was markedly improved with the implementation of the mark-recapture project on the U.S./Canada border in 1980. Reconstruction of runs from 1980 onward was more accurate. In the following section, spawner-recruit relationships were fit to both the full data set from the 1974 – 1995 brood years, and to a reduced data set from the 1980 – 1995 brood years.

Aggregate Yukon River Fall Chum Salmon

Spawner-Recruit Relationships Based on the 1974 – 1995 Brood Year Data. Fall chum salmon escapements have been used to reconstruct the aggregate run for the Yukon River annually since 1974. Over the 26-year period of 1974 to 1999 the aggregate fall chum salmon escapement in the Yukon River has averaged 508,011 fish, ranging from a low of 179,828 fish in 1982 to a high of 1,465,213 fish in 1975 (Table 16). Thus contrast in spawning abundance is about 8.1-fold, a high and meaningful level of variation in annual spawning abundance.

According to the CTC (1999), the following guidelines concerning contrast in spawning abundance can be used in statistical stock-recruit analyses:

> *"When estimates of spawning abundance are similar – the range is less than 4 times the smallest spawning abundance – statistical stock-recruit analysis is likely to produce a poor estimate of S_{MSY}.*
>
> *When range in spawning abundance is 4 to 8 times the smallest level, statistical stock-recruit analysis should produce better estimates of S_{MSY}, so long as measurement error is not extreme and some of the production-to-spawner ratios are below one at higher levels of spawning abundance.*
>
> *When range is more than 8, statistical analysis should produce the best estimates, so long as some of the production-to-spawner ratios are below one at higher levels of spawning abundance."*

With a contrast of spawning escapements of 8.1-fold, the Yukon River fall chum salmon analysis fits into the high contrast category identified by the CTC (1999) general methods, and thus production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Twenty-two brood years of recruits are estimated and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, the criteria under the high contrast category is met, and there are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reconstructed aggregate Yukon River fall chum salmon escapement and recruit data (Figure 4) was significant (p-value <0.001) with a corrected R-square of 0.40 indicating significant density dependence (Table 20) and statistical definition of a MSY escapement level. The residual plots for the Ricker-type spawner-recruit relationship (Figure 5) indicate a significant auto-correlation (lag 1 year autocorrelation = 0.43, $p = 0.025$). To correct for the autocorrelation, a Ricker model with a first order auto-regressive parameter was fit to the data. The auto-regressive model gave a significant improvement in fit ($p < 0.001$) with corrected R-Square of 0.55 (Table 20). Analyses of residuals (Figure 7) from the auto-regressive Ricker model indicate no trend or significant auto-correlation.

Analysis of the auto-regressive spawner-recruit relationship for the aggregate Yukon River fall chum salmon stock resulted in an estimate of 492,293 spawners as the MSY escapement level (Table 20). The spawner-recruit relationship developed estimated that maximum surplus yield from the aggregate Yukon River stock of chum salmon is 314,645 on average. If the aggregate Yukon River stock of fall chum salmon were managed at the indicated MSY escapement level of 492,293 spawners per year, a fishery yield of 314,645 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 39%. Recruits from the two most recent brood years have been the lowest in the series (Figure 5).

The mean bootstrap estimate of MSY escapement for the aggregate Yukon River stock of fall chum salmon is 422,795 spawners, and the coefficient of variation for this mean statistic is 18.9% (Table 20). The 90% confidence interval for the estimated MSY escapement level for the aggregate Yukon River fall chum salmon stock is estimated at 335,745 to 533,105 spawners (Table 20). The bootstrap mean estimate of the MSY escapement level (422,795) is slightly lower than that estimated (492,293) based the linearized auto-regressive Ricker model fit by maximum likelihood, indicating a negative bias of -16.4% (Table 20).

Based on the auto-regressive model fit to the full data set, the escapement point value for the aggregate Yukon River fall chum salmon stock is 492,293 spawners. The biological escapement goal for the aggregate Yukon River fall chum salmon is **327,000 to 677,000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

The autocorrelation in the residuals from the Ricker spawner-recruit relationship fit to the 1975 – 1995 data is extreme, and due to the positive correlation between the productivity (i.e. return per spawner) of a brood year to the previous brood year (Figure 6). The productivity of Yukon River fall chum salmon is clearly cycling (Figure 6), with episodes of increasing productivity followed by an abrupt change to an episode of declining productivity. The length of these productivity episodes is variable but roughly equal to the lifespan of the Yukon fall chum salmon. This phenomenon suggests that the spawner-recruitment relationship is strongly regulating the abundance of this population. This dynamic is consistent with that of an unexploited or lightly exploited population with a compensatory spawner-recruit relationship (Ricker 1954).

There is extreme uncertainty in the magnitude of the 1975 escapement based on the reconstruction of the 1975 run. The 1975 escapement exerts a large influence on the estimated relationship between escapement and recruitment for this stock. The auto-regressive Ricker model, with a high first order autocorrelation coefficient (0.71) and a flat underlying stock and recruitment relationship (alpha = 2.41 and MSY exploitation rate of 39%) fit the data well (Figure 4 upper panel). Here the auto-regressive properties of the model fits the cycling of productivity inherent in the main cluster of data, and the flat productivity properties fit the extreme 1975 data point.

Spawner-Recruit Relationships Based on the 1980 – 1995 Brood Year Data. Over the 20-year period of 1980 to 1999 the aggregate fall chum salmon escapement in the Yukon River has averaged 471,030 spawning fish, ranging from a low of 179,828 fish in 1982 to a high of 1,055,603 fish in 1995 (Table 16). Thus, contrast in spawning abundance is about 5.9-fold, a meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 5.9, the Yukon River fall chum salmon analysis fits into the middle contrast category identified by the CTC (1999) general methods and thus measurement errors and production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Sixteen brood years of recruits are estimated (Table 16) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, one of the criteria for the middle category is met. The other criterion, measurement error, is a more difficult problem. Although annual spawning escapements have been estimated, variances associated with these estimates are available for only a portion of the components of the reconstructed escapement. The escapement assessment methodologies used for Sheenjek and Chandalar River sonar counts, Fishing Branch weir counts, and the various mark-recapture estimates have been rigorous and without bias. It seems likely that the coefficients of variation associated with the annual escapement assessments in recent years is likely less than 10%, but that is based on opinion, not on sampling information. If this is a correct assumption, measurement errors are minor. There is good reason to believe that measurement errors associated with annual escapements are not extreme. Thus the second condition listed by the CTC (1999) is believed to be met. There are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reduced aggregate Yukon River fall chum salmon data set was significant (p-value < 0.001) with a corrected R-Square of 0.60 indicating significant density dependence (Table 20, Figure 4 lower panel) and statistical definition of the MSY escapement level. The residual plots for the Ricker-type spawner-recruit relationship (Figure 8) indicate no significant auto-correlation. The residual patterns in the estimated spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 8, respectively). The Ricker spawner-recruit model explains the cycling of productivity that is in the reduced data set (Figure 6). The productivity has been below that expected for the most recent three brood years (Figure 8).

Analysis of the Ricker spawner-recruit relationship for the aggregate Yukon River fall chum salmon stock resulted in an estimate of 287,469 spawners as the MSY escapement level (Table 20). The spawner-recruit relationship developed estimated that maximum surplus yield from the aggregate Yukon River stock of chum salmon is 513,753 on average. If the aggregate Yukon River stock of fall chum salmon were managed at the indicated MSY escapement level of 287,469 spawners per year, a fishery yield of 513,753 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 64.1%.

The mean bootstrap estimate of MSY escapement for the aggregate Yukon River stock of fall chum salmon is the Ricker spawner-recruit model is 290,599 spawners and the coefficient of variation for this mean statistic is 12.3% (Table 20). The 90% confidence interval for the estimated MSY escapement level for the aggregate Yukon River fall chum salmon stock is estimated at 239,411 to 354,353 spawners (Table 20). The bootstrap mean estimate of the MSY escapement level (290,599) is slightly higher than that estimated (287,469) based on linear regression, indicating a slight positive bias of 1.1% (Table 20).

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the aggregate Yukon River fall chum salmon stock is 287,469 spawners. The biological escapement goal for the aggregate Yukon River fall chum salmon is **185,000 to 408,000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Tanana River Fall Chum Salmon

Spawner-Recruit Relationships Based on the 1974 – 1995 Brood Year Data. Fall chum salmon escapements in the Tanana River have been reconstructed annually since 1974. Over the 26-year period of 1974 to 1999, the aggregate fall chum salmon escapement in the Tanana River has averaged 147,640 spawning fish while ranging from a low of 38,118 spawning fish in 1982 to a high of 322,686 in 1995 (Table 17). Thus contrast in spawning abundance is approximately 8.5-fold, a high and meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 8.5-fold, the Tanana River fall chum salmon analysis fits into the high contrast category identified by the CTC (1999) general methods, and thus production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Twenty-two brood years of recruits are estimated (Table 17) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, the criteria under the high contrast category is met, and there are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the full data set for the reconstructed Tanana River fall chum salmon runs and recruit data was highly significant (p-value <0.001) with a corrected R-Square of 0.56 indicating significant density dependence (Table 21, Figure 9) and a statistical definition of the MSY escapement level. Analysis of the spawner-recruit relationship for the Tanana River fall chum salmon stock resulted in an estimate of 95,287 spawners as the MSY escapement level (Table 21). The spawner-recruit relationship developed estimated that maximum surplus yield from the Tanana River stock of chum salmon is 218,649, on average. If the Tanana River stock of fall chum salmon were managed at the indicated MSY escapement level of 95,287 spawners per year, a fishery yield of 218,649 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 69.6%. The residual patterns in the estimated spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 10, respectively). The production in the most recent four brood years has been lower than average (Figure 10).

The mean bootstrap estimate of MSY escapement for the Tanana River stock of fall chum salmon using the Ricker spawner-recruit model is 96,606 spawners and the coefficient of variation for this mean statistic is 12.4% (Table 21). The 90% confidence interval for the estimated MSY escapement level for the Tanana River fall chum salmon stock is estimated at 80,745 to 117,771 spawners (Table 21). The bootstrap mean estimate of the MSY escapement level (96,606) is slightly higher than that estimated (95,287) based on linear regression, indicating a slight positive bias of 1.4% (Table 21).

Based on the Ricker model fit to the full data set, the MSY escapement point value for the aggregate Tanana River fall chum salmon stock is 95,287 spawners. The biological escapement goal for the Tanana River fall chum salmon is **61,000 to 136, 000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Please note that the Tanana River fall chum salmon BEG is in units of reconstructed Tanana River escapement, whereas, the long term monitoring of Tanana River escapement is indexed by the Toklat River escapement surveys and the Delta River escapement surveys. The biological escapement goals for the Tanana River should be expressed in units consistent with these long-term escapement indices. BEG's were derived for the Toklat and Delta Rivers by partitioning of the Tanana River BEG based on the average historical, 1974 – 1999, portion of the Tanana River reconstructed escapements attributed to the Toklat and Delta Rivers, respectively. These were 24.1% and 9.3%, respectively.

Based on the Ricker model fit to the full data set, the MSY escapement point value for the Toklat River fall chum salmon stock is 22,962 spawners, which is 24.1 percent of the Tanana River fall chum MSY escapement point value. The biological escapement goal for the Toklat River fall chum salmon is **15,000 to 33,000 total spawners** per year.

The best available scientific estimate of the MSY escapement point value for the Delta River fall chum salmon stock is 8,900 spawners which is 9.3 % percent of the Tanana River fall chum MSY escapement point value. The biological escapement goal for the Delta River fall chum salmon is **6,000 to 13,000 total spawners** per year.

Spawner-Recruit Relationships Based on the 1980 – 1995 Brood Year Data. The Ricker-type spawner-recruit relationship was fit to the reduced data set for the reconstructed Tanana River fall chum salmon runs. The results (Table 21, Figure 9 lower panel, and Figure 11) were almost identical to the model fit to the full data set as discussed above.

Upper Yukon River Tributary Fall Chum Salmon

Spawner-Recruit Relationships Based on the 1974 – 1995 Brood Year Data. Fall chum salmon escapements for the Upper Yukon River tributary have been reconstructed annually since 1974. Over the 26-year period of 1974 to 1999, the aggregate fall chum salmon escapements in the Upper Yukon River tributaries have averaged 286,944 spawning fish, ranging from a low of 95,564 spawning fish in 1984 to a high of 1,082,228 in 1975 (Table 18). Thus contrast in spawning abundance is approximately 11.3-fold, a high and meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 11.3-fold, the Upper Yukon River tributary fall chum salmon analysis fits into the high contrast category identified by the CTC (1999) general methods and thus production to spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Twenty-two brood years of recruits are estimated (Table 18) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, the criteria under the high contrast category is met, and there are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reconstructed Upper Yukon River tributary fall chum salmon runs and recruit data was significant (p-value = 0.0014) with a corrected R-Square of 0.38 indicating significant density dependence (Table 22) and statistical definition of the MSY escapement level. An examination of the residuals in the Ricker-type spawner-recruit relationship indicates a significant auto-correlation (lag 1 year auto-correlation = 0.57, p = 0.0038). To correct for the autocorrelation, a Ricker model with a first order auto-regressive parameter was fit to the data. The auto-regressive model gave a significant improvement in fit ($p < 0.001$) with corrected R-Square of 0.51 (Figure 12, upper panel). The residual patterns in the estimated auto-regressive Ricker spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 13, respectively).

Analysis of the auto-regressive spawner-recruit relationship for the Upper Yukon River tributary fall chum salmon stock resulted in an estimate of 228,097 spawners as the MSY escapement level (Table 22). The spawner-recruit relationship developed estimated that maximum surplus yield from the Upper Yukon River tributary stock of chum salmon is 116,710 on average. If the Upper Yukon River tributary stock of fall chum salmon were managed at the indicated MSY escapement level of 228,097 spawners per year, a fishery yield of 116,940 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 33.9%. Recruits from the two most recent brood years have been the lowest in the series (Figure 12).

The mean bootstrap estimate of MSY escapement for the Upper Yukon River tributary stock of fall chum salmon is 221,822 spawners and the coefficient of variation for this mean statistic is 15.5% (Table 22). The 90% confidence interval for the estimated MSY escapement level for the Upper Yukon River tributary fall chum salmon stock is estimated at 168,649 to 298,830 spawners (Table 22). The bootstrap mean estimate of the MSY escapement level (221,822) is lower than that estimated (228,097) based the linearized auto-regressive Ricker model fit by maximum likelihood, indicating a negative bias of –2.8% (Table 22).

Based on the auto-regressive model fit to the full data set, the MSY escapement point value for the Upper Yukon River tributary fall chum salmon stock is 228,097 spawners. The biological escapement goal for the Upper Yukon River tributary fall chum salmon is **152,000 to 312,000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Note that the Upper Yukon River tributary fall chum salmon BEG is in units of reconstructed Upper Yukon River tributary escapement. Whereas the long term monitoring of Upper Yukon River tributary escapement is indexed by the Chandalar and Sheenjek River sonar counts, and the Fishing Branch River escapement counts. The biological escapement goals for the Upper Yukon River tributary should be expressed in units consistent with these long-term escapement indices. BEG's were derived for the Chandalar, Sheenjek and Fishing Branch Rivers by partitioning of the Upper Yukon River tributary fall chum salmon BEG based on the average historical, 1974 – 1999, portion of the Upper Yukon River tributary reconstructed escapements of 48.6 %, 33.4 %, and 18.0%, respectively.

Based on the auto-regressive model fit to the full data set, the MSY escapement point value for the Chandalar River fall chum salmon stock is 110,879 spawners, which is 48.6 percent of the Upper Yukon River tributary fall chum salmon MSY escapement point value. The biological escapement goal for the Chandalar River fall chum salmon is **74,000 to 152,000 total spawners** per year.

Based on the auto-regressive model fit to the full data set, the MSY escapement point value for the Sheenjek River fall chum salmon stock is 76,222 spawners, which is 33.4% percent of the Upper Yukon River tributary fall chum salmon MSY escapement point value. The biological escapement goal for the Sheenjek River fall chum salmon is **50,000 to 104,000 total spawners** per year.

Based on the auto-regressive model fit to the full data set, the MSY escapement point value for the Fishing Branch River fall chum salmon stock is 40,996 spawners, which is 18% percent of the Upper Yukon River tributary fall chum salmon MSY escapement point value. The biological escapement goal for the Fishing Branch River fall chum salmon is **27,000 to 56,000 total spawners** per year.

Spawner-Recruit Relationships Based on the 1980 – 1995 Brood Year Data. Over the 20-year period of 1980 to 1999, the aggregate fall chum salmon escapements in the Upper Yukon River tributaries have averaged 254,356 spawning fish, ranging from a low of 95,564 spawning fish in 1982 to a high of 574,825 in 1995 (Table 18). Thus contrast in spawning abundance is approximately 6.0-fold, a meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 6.0 the Upper Yukon River tributary fall chum salmon analysis fits into the middle contrast category identified by the CTC (1999) general methods, and thus measurement errors and production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Sixteen brood years of recruits are estimated (Table 18) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, one of the criteria for the middle category is met. The other criterion, measurement error, is a more difficult problem to evaluate. Although annual spawning escapements have been estimated, variances associated with these estimates are available for only a portion of the components of the reconstructed escapement. The escapement assessment methodologies used for Sheenjek and Chandalar River sonar counts, Fishing Branch River weir counts, and the various mark-recapture estimates have been rigorous and without bias. It seems likely that the coefficients of variation associated with the annual escapement assessments in recent years is likely less than 10%, but that is based on opinion, not on sampling information. If this is a correct assumption, measurement errors are minor. There is good reason to believe that measurement errors associated with annual escapements are not extreme. And thus, the second condition listed by the CTC (1999) is believed to be met. There are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reduced Upper Yukon River tributary fall chum salmon data set was significant (p-value < 0.001) with a corrected R-square of 0.60 indicating significant density dependence (Table 22, Figure 12 lower panel) and statistical definition of the MSY escapement level. The residual plots for the Ricker-type spawner-recruit relationship (Figure 14) indicate no significant auto-correlation. The residual patterns in the estimated spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 14, respectively).

Analysis of the Ricker spawner-recruit relationship for the Upper Yukon River tributary fall chum salmon stock resulted in an estimate of 140,817 spawners as the MSY escapement level (Table 22). The spawner-recruit relationship developed estimated that maximum surplus yield from the Upper Yukon River tributary stock of chum salmon is 223,442 on average. If the Upper Yukon River tributary stock of fall chum salmon were managed at the indicated MSY escapement level of 140,817 spawners per year, a fishery yield of 223,442 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 61.3%.

The mean bootstrap estimate of MSY escapement for the Upper Yukon River tributary stock of fall chum salmon using the Ricker spawner-recruit model is 141,501 spawners and the coefficient of variation for this mean statistic is 11.8% (Table 22). The 90% confidence interval for the estimated MSY escapement level for the Upper Yukon River tributary fall chum salmon stock is estimated at 118,601 to 172,409 spawners (Table 22). The bootstrap mean estimate of the MSY escapement level (141,501) is slightly higher than that estimated (140,817) based on linear regression, indicating a slight positive bias of 0.5% (Table 22).

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the Upper Yukon River tributary fall chum salmon stock is 140,817 spawners. The biological escapement goal for the Upper Yukon River tributary fall chum salmon is **91,000 to 199, 000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Note that the Upper Yukon River tributary fall chum salmon BEG is in units of reconstructed Upper Yukon River tributary escapement, whereas, the long term monitoring of Upper Yukon River tributary escapement is indexed by Chandalar and Sheenjek River sonar counts, and the Fishing Branch River escapement counts. The biological escapement goals for the Upper Yukon River tributary should be expressed in units consistent with these long-term escapement indices. BEG's were derived for the Chandalar, Sheenjek, and Fishing Branch Rivers by partitioning of the Upper Yukon River tributary fall chum salmon BEG based on the average historical, 1980 – 1999, portion of the Upper Yukon River tributary reconstructed escapements of 49.0 %, 34.4 %, and 16.5%, respectively.

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the Chandalar River fall chum salmon stock is 69,045 spawners which is 49.0 percent of the Upper Yukon River tributary fall chum MSY escapement point value. The biological escapement goal for the Chandalar River fall chum salmon is **45,000 to 98,000 total spawners** per year.

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the Sheenjek River fall chum salmon stock is 48,509 spawners which is 34.4% percent of the Upper Yukon River tributary fall chum MSY escapement point value. The biological escapement goal for the Sheenjek River fall chum salmon is **31,000 to 69,000 total spawners** per year.

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the Fishing Branch River fall chum salmon stock is 23,263 spawners which is 16.5% percent of the Upper Yukon River tributary fall chum MSY escapement point value. The biological escapement goal for the Fishing Branch River fall chum salmon is **15,000 to 33,000 total spawners** per year.

Upper Yukon River Mainstem Fall Chum Salmon

Spawner-Recruit Relationships Based on the 1974 – 1995 Brood Year Data. Fall chum salmon escapements in the Upper Yukon River mainstem have been reconstructed annually since 1974. Over the 26-year period of 1974 to 1999, the aggregate fall chum salmon escapements in the Upper Yukon River mainstem have averaged 73,427 spawning fish while ranging from a low of 22,912 spawning fish in 1980 to a high of 260,307 in 1975 (Table 19). Thus contrast in spawning abundance is approximately 11.4-fold, a high and meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 11.4-fold, the Upper Yukon River mainstem fall chum salmon analysis fits into the high contrast category identified by the CTC (1999) general methods and thus production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Twenty-two brood years of recruits are estimated (Table 19) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, the criteria under the high contrast category is met, and there are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reconstructed Upper Yukon River mainstem fall chum salmon runs and recruit data was significant (p-value < 0.001) with a corrected R-Square of 0.48 indicating significant density dependence (Table 23) and statistical definition of MSY escapement level. An examination of the residuals in the Ricker-type spawner-recruit relationship indicates a significant auto-correlation (lag 1 year auto-correlation = 0.44, $p = 0.021$). To correct for the autocorrelation, a Ricker model with a first order auto-regressive parameter was fit to the data. The auto-regressive model gave a significant improvement in fit ($p < 0.001$) with corrected R-Square of 0.60 (Figure 15, upper panel). The residual patterns in the estimated auto-regressive Ricker spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 16, respectively).

Analysis of the auto-regressive spawner-recruit relationship for the Upper Yukon River mainstem fall chum salmon stock resulted in an estimate of 91,852 spawners as the MSY escapement level (Table 23). The spawner-recruit relationship developed estimated that maximum surplus yield from the Upper Yukon River mainstem stock of chum salmon is 116,521 on average. If the Upper Yukon River tributary stock of fall chum salmon were managed at the indicated MSY escapement level of 91,852 spawners per year, a fishery yield of 116,521 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 55.9 %. The recruits from the two most recent brood years have been lower than expected (Figure 16).

The mean bootstrap estimate of MSY escapement for the Upper Yukon River mainstem stock of fall chum salmon is 79,353 spawners and the coefficient of variation for this mean statistic is 14.1% (Table 23). The 90% confidence interval for the estimated MSY escapement level for the Upper Yukon River mainstem fall chum salmon stock is estimated at 59,968 to 103,695 spawners (Table 23). The bootstrap mean estimate of the MSY escapement level (79,353) is lower than that estimated (91,852) based the linearized auto-regressive Ricker model fit by maximum likelihood, indicating a negative bias of –15.8% (Table 23).

Based on the auto-regressive model fit to the full data set, the MSY escapement point value for the Upper Yukon River mainstem fall chum salmon stock is 91,852 spawners. The biological escapement goal for the Upper Yukon River mainstem fall chum salmon is **60,000 to 129,000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Spawner-Recruit Relationships Based on the 1980 – 1995 Brood Year Data. Over the 20-year period of 1980 to 1999, the aggregate fall chum salmon escapements in the Upper Yukon River tributaries have averaged 66,912 spawning fish while ranging from a low of 22,912 spawning fish in 1980 to a high of 158,092 in 1995 (Table 19). Thus contrast in spawning abundance is approximately 6.9-fold, a meaningful level of variation in annual spawning abundance.

With a contrast of spawning escapements of 6.9 the Upper Yukon River mainstem fall chum salmon analysis fits into the middle contrast category identified by the CTC (1999) general methods and thus measurement errors and production-to-spawner levels are important in determining if data will be adequate to conduct a statistical analysis. Sixteen brood years of recruits are estimated (Table 19) and several of the annual escapements with higher values have production-to-spawner ratios below one. Thus, one of the criteria for the middle category is met. The other criterion, measurement error, is a more difficult problem to evaluate. Although annual spawning escapements have been estimated, variances associated with these estimates are available for only a portion of the components of the reconstructed escapement. The escapement assessment methodologies used for the upper Yukon River mainstem was a mark-recapture estimates and is rigorous and without bias. The coefficients of variation associated with the annual escapement assessments are likely less than 10%. Thus, measurement errors are minor and the second condition listed by the CTC (1999) is met. There are good technical reasons to believe that stock-recruit analysis will lead to useable estimates of the escapement level that produces maximum sustained yield (S_{MSY}).

The Ricker-type spawner-recruit relationship fit to the reduced Upper Yukon River mainstem fall chum salmon data set was significant (p-value < 0.001) with a corrected R-Square of 0.66 indicating significant density dependence (Table 23, Figure 15 lower panel) and statistical definition of the MSY escapement level. The residual plots for the Ricker-type spawner-recruit relationship (Figure 17) indicate no significant auto-correlation. The residual patterns in the estimated spawner-recruit relationship when plotted through time and against brood year escapements appear random (upper and lower panels of Figure 17, respectively).

Analysis of the Ricker spawner-recruit relationship for the Upper Yukon River mainstem fall chum salmon stock resulted in an estimate of 48,770 spawners as the MSY escapement level (Table 23). The spawner-recruit relationship developed estimated that maximum surplus yield from the Upper Yukon River mainstem stock of chum salmon is 117,682 on average. If the Upper Yukon River mainstem stock of fall chum salmon were managed at the indicated MSY escapement level of 48,770 spawners per year, a fishery yield of 117,682 fish is estimated to be provided, on average, indefinitely. The exploitation rate in this case would be 70.7%.

The mean bootstrap estimate of MSY escapement for the Upper Yukon River mainstem stock of fall chum salmon using the Ricker spawner-recruit model is 49,100 spawners and the coefficient of variation for this mean statistic is 11.9% (Table 23). The 90% confidence interval for the estimated MSY escapement level for the Upper Yukon River mainstem fall chum salmon stock is estimated at 40,116 to 58,751 spawners (Table 23). The bootstrap mean estimate of the MSY escapement level (49,100) is slightly higher than that estimated (48,770) based on linear regression, indicating a slight positive bias of 0.7% (Table 23).

Based on the Ricker model fit to the reduced data set, the MSY escapement point value for the Upper Yukon River mainstem fall chum salmon stock is 48,770 spawners. The biological escapement goal for the Upper Yukon River mainstem fall chum salmon is **31,000 to 70, 000 total spawners** per year. The BEG is based on the range of escapements for which expected yield is greater than 90% of MSY.

Discussion

Two alternative methods of estimating biological escapement goals for the various stocks of Yukon River fall chum salmon have been presented. One method is based on a spawner-recruit analysis of the full data set, including the estimates of recruits from parent escapement for 1974 to 1995 brood years. The second method is based on a spawner-recruit analysis of a reduced data set, including estimates of recruits and parent escapements from the 1980 – 1995 brood years.

The results based on the two methods are strikingly different, with the estimates of BEG based on the model fit to the reduced data set much lower than those based on the model fit to the full data set. In addition, the pattern of residuals from the model based on the full data set show extreme auto-correlation, for the aggregate Yukon River, Upper Yukon River tributary, and the Upper Yukon River mainstem stock. The estimates of MSY escapement based on the full data set model were biased for the aggregate Yukon River, Upper Yukon River tributary, and Upper Yukon River mainstem fall chum salmon stocks, and estimates were biased 16.4%, 2.8%, and 15.8% high, respectively. Correcting for the auto-correlation resulted in underlying spawner-recruit relationships with a much lower productivity than the spawner-recruit relationship estimated from the full data set model (Tables 21, 22 and 23). This lower productivity of the auto-regressive Ricker model estimated from the full data appears to be inconsistent with that observed for these stocks (Figure 4 upper panel; Figure 12 upper panel) for most brood years. Estimates of average yield for regular ranges of escapement level (i.e., a Markov Table) shows that yields observed for the Upper Yukon River tributary stock, for escapements in the range 150 – 500 thousand were 2-3 times higher (Table 25) than the maximum sustained yield level estimated based on the full data set model.

Substantial improvements in the assessment of Yukon River fall chum salmon escapements occurred in 1980 with the implementation of the DFO mark-recapture projects at the U.S./Canada border, and in 1995 with implementation of the Chandalar River sonar project and the Upper Tanana River mark-recapture project. In the reconstructed escapements the proportion of the expanded escapement observed in escapement enumeration projects for the period 1974 – 1979, 1980 – 1994, and after 1995 was 36%, 41% and 100%, respectively. The full data set includes the 1974 to 1979 brood years where highest uncertainty exists in the reconstructed escapement. The differences between the two models were greatest for the Upper Yukon River tributary and the aggregate Yukon River. In my opinion, the above mentioned statistical problems with the full data model and inconsistencies with observed productivity was due to potential errors in the escapement assessments for brood years before 1980, and particular for the 1975 brood year.

The stock and recruitment models fit to the reduced data set produced very consistent results among stocks, with high productivity, very good statistical fit to the data, and very good statistical properties in residual patterns including a lack of auto-correlation. The escapement levels for all stocks was very high in 1994 and 1995; however, the production for these brood years was either the lowest or among the lowest observed in the data series for all stocks. A sequential estimation of spawner-recruit model for the reduced data set, using 1980 – 1993 brood years, 1980 – 1994, etc. would show a reduced MSY escapement level with the inclusion of the more recent data. The question is whether the reduced production from the 1994 and 1995 brood years was due to density dependence or to density independent environmental factors. This question cannot be ascertained from the data. Because of the uncertainty as to the cause of the recent poor production and the influence of the recent brood years on the estimated MSY escapement, there is uncertainty in the estimates of MSY escapement goals based on the models fit to the reduced data set. In view of this uncertainty, it is recommended that the biological escapement goals for the Tanana River, Upper Yukon River tributary, and Upper Yukon River mainstem stocks be set based on the Ricker or auto-regressive Ricker fit to the full data set.

As an independent check on the recommended biological escapement goals, tables of average yields observed for a range of escapement levels (i.e., Markov Tables) were constructed and presented in Table 24 for the aggregate Yukon River and Tanana River while Table 25 presents the Upper Yukon River tributary and Upper Yukon River mainstem stocks. With the exception of the Upper Yukon River mainstem stock, the recommended biological escapement goals are consistent with the range of escapements that were observed to produce the highest surplus production. For the Upper Yukon River mainstem, escapement above 80 thousand, which is within the recommended BEG for that stock, produced very poorly (Table 25).

There exists significant populations of fall chum salmon in Yukon River tributaries that were not monitored. The magnitude of the escapement is at least 25,000 fish based on limited monitoring of fall chum salmon escapement in the Koyukuk and Kantishna Rivers. The effect of this under assessment of escapement would be to underestimated the escapement in the reconstructed runs of the Yukon River; and to overestimate catch (i.e., some catch of the unmonitored stocks would be assigned to the monitored stocks) in the reconstructed runs of the individual stocks of chum salmon in the Yukon River. Because exploitation rates were in the range of 20% - 60%, and the unmonitored escapement is a very small relative to the monitored escapement of Yukon River fall chum run, the magnitude of over-estimated utilization in the reconstructed runs for the tributary stocks is very small. The biological escapement goal for the aggregate Yukon River stock should be set as the sum of the individual stock biological escapement goals and this sum adjusted upwards by 25,000 to provide a rough correction for unmonitored escapement. The recommended BEG for the aggregate Yukon River fall chum salmon is 300,000 to 600,000 fish.

STATUS OF YUKON RIVER FALL CHUM SALMON STOCKS GIVEN THE RECOMMENDED MSY ESCAPEMENT GOALS

Escapements for various stocks of fall chum salmon within the Yukon River drainage are generally within or above Biological Escapement Goals (Table 26).

For the aggregate Yukon River stock, from 1974 to 1999, escapements in 6 of 26 years (23.1%) were below, 13 of 26 years (50%) were within, and 7 of 26 years (26.9%) were above the biological escapement goal range (Table 26, Figure 18). The 5-year moving average of escapement, which is the indicator of stock concern as specified in the Sustainable Salmon Fisheries Policy, was within the BEG range, except for a few years in the late 1970s and mid-1990s when the trend in escapement was above the BEG range. This indicates the aggregate Yukon River fall chum salmon stock is healthy and somewhat underutilized in some years.

For the aggregate Tanana River stock, from 1974 to 1999, escapements in 1 of 26 years (3.8%) were below, 13 of 26 years (50%) were within, and 12 of 26 years (46.2%) were above the biological escapement goal range (Table 22, Figure 19). The 5-year moving average of the Tanana River escapement, which is the indicator of stock concern as specified in the Sustainable Salmon Fisheries Policy, and was within the BEG range except for a few years in the late 1970s and mid-1980s to mid-1990s when the trend in escapement was above the BEG range. This indicates the Tanana River fall chum salmon stock as a whole is healthy and somewhat underutilized in some years.

For the Toklat River stock within the Tanana River drainage, escapement in 6 of 26 years (23.1%) was below the BEG range (Table 26, Figure 19). This occurrence of weak runs in recent years is more frequent than observed for the Tanana and Delta Rivers. The Toklat River escapement has been below the BEG range in four years since 1990. The moving average of escapement is expected to fall below the BEG range if conditions of low productivity persist and may indicate a management concern for this stock. However, the trend in escapement for the Toklat River is similar to the Tanana and Delta Rivers (Figure 19). The indication of management concern for the Toklat River may be an artifact of the method used to apportion the MSY escapement goal estimated for the Tanana River to the tributary systems within the Tanana River stock. The MSY escapement goal proposed for the Toklat system is very sensitive to errors in the average proportion of the Tanana River run attributed to the Toklat River system.

For the Upper Yukon River tributary stock, from 1974 to 1999, escapements in 7 of 26 years (26.9%) were below, 12 of 26 years (46.2%) were within, and 7 of 26 years (26.9%) were above the biological escapement goal range (Table 26, Figure 20). The 5-year moving average of the Upper Yukon River tributary escapement, which is the indicator of stock concern as specified in the Sustainable Salmon Fisheries Policy, was within the BEG range, except for a few years in the late 1970s and mid-1990s when the trend in escapement was above the BEG range. This indicates the Upper Yukon River tributary fall chum salmon stock is healthy and may be underutilized in some years. The escapement for the most recent two years has been below the BEG range.

For the Upper Yukon River mainstem stock, from 1974 to 1999, escapements in 12 of 26 years (46.2%) were below, 12 of 26 years (46.2%) were within, and 2 of 26 years (7.7%) were above the biological escapement goal range (Table 26, Figure 20). The 5-year moving average of the Upper Yukon River mainstem escapement, which is the indicator of stock concern as specified in the Sustainable Salmon Fisheries Policy, was within the BEG range in recent years.

RECOMMENDATIONS

Biological escapement goals are recommended for the following Yukon River fall chum salmon stocks.

Drainage-wide Yukon River fall chum salmon: 300,000 to 600,000 total spawners per year.

Tanana River fall chum salmon: 61,000 to 136,000 total spawners per year, as estimated by the sum of the Upper Tanana River escapement based on a mark-recapture project and the Toklat River survey counts.

Delta River fall chum salmon: 6,000 to 13,000 total spawners per year.

Toklat River fall chum salmon: 15,000 to 33,000 total spawners per year.

Upper Yukon River Tributary fall chum salmon: 152,000 to 312,000 total spawners per year, as estimated by the sum of the Chandalar and Sheenjek River sonar counts, and the Fishing Branch River weir count.

Chandalar River fall chum salmon: 74,000 to 152,000 total spawners per year.

Sheenjek River fall chum salmon: 50,000 to 104,000 total spawners per year.

Fishing Branch River fall chum salmon: 27,000 to 56,000 total spawners per year. However U.S./Canadian Negotiations determine agreed upon levels of passage.

Upper Yukon River Mainstem fall chum salmon: 60,000 to 129,000 total spawners per year. However U.S. /Canadian Negotiations determine agreed upon levels of passage.

It is also recommended that this biological escapement goal analysis be updated in approximately five years. The principal weakness of the analysis is the incomplete assessment of Yukon River fall chum salmon escapements prior to 1980. Prior to 1980 there was no assessment of the Upper Yukon River mainstem escapement, additionally the weir and sonar counts in the Porcupine drainage were not consistently conducted. Reconstructed runs prior to 1982 were mostly based on expansion of less precise and accurate foot and aerial survey counts. Thus reconstructed runs prior to 1982 were likely sensitive to errors in escapement assessment exacerbated by the incomplete assessment of escapement.

A few more years of spawner-recruit observations under the present stock assessment program of practically complete escapement enumeration of Yukon River fall chum salmon should clarify the uncertainty in the causes of the productivity in recent brood years. When more years of data are available, it is recommended biological escapement goals be re-evaluated from estimated recruits from 1982 and later brood years.

It is recommended that the existing stock assessment program be continued, advanced and improved upon. Recommended changes include:

1. Develop a more complete estimate of escapement to Yukon River drainage. I recommend that assessment programs be developed for the Kantishna/Toklat River and Koyukuk River.

2. The Pilot Station sonar estimate of escapement appears to be conservative and prior to 1995 has proven unreliable in assessing abundance of fall chum salmon in-season. This project provides

information that is critical to implementation of effective management. The department should explore the use of other equipment and techniques to increase the assessment accuracy of this project.

LITERATURE CITED

Alaska Department of Fish and Game. 1992. Yukon Area commercial and subsistence salmon fisheries 1992 management plan. ADF&G Commercial Fisheries Division, RIR 3A92-10. Anchorage.

Barton, L. H. 1986. Historical data expansion of Delta river fall chum salmon escapements and 1985 population estimates based upon replicate aerial and ground surveys. AYK Region, Yukon Salmon Escapement Report No., 29. Department of Fish and Game, Commercial Fisheries Division, 1300 College Rd., Fairbanks, AK 99701-1599.

Barton, L. W. 1995. Sonar enumeration of fall chum salmon on the Sheenjek River, 1988 - 1992. Technical Fishery Report 95-06. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, P.O. Box 25526, Juneau, Alaska, 99802-5526.

Barton, L. H. 1997. Salmon escapement assessments in the Toklat River, 1994. Regional Information Report 3A97-35. Department of Fish and Game, Commercial Fisheries Division, 333 Raspberry Road, Anchorage, AK 99518

Barton, L. H. 1999A. Fall chum/coho salmon escapement goal review. State of Alaska Memorandum (10 pages), Department of Fish and Game, Commercial Fisheries Division. Dated March 17, 1999, written to Distribution, and available from Department of Fish and Game, Commercial Fisheries Division, 333 Raspberry Road, Anchorage, AK 99518.

Barton, L. H. 1999B. Yukon River fall salmon run sizes, 1999. Memorandum (18 pages), Department of Fish and Game, Commercial Fisheries Division. Dated April 21, 1999, written to Distribution, and available from Department of Fish and Game, Commercial Fisheries Division, 333 Raspberry Road, Anchorage, AK 99518.

Bergstrom, D. J., K. C. Schultz, V. Golembeski, B. M. Borba, D. Huttunen, L. H. Barton, T. L. Lingnau, R. R. Holder, J. S. Hayes, K. R. Boeck, and W. H. Busher. 1999. Annual Management Report Yukon Area, 1998. Regional Informational Report No. 3A99-26, Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region, 333 Raspberry Road, Anchorage, AK 99518. 256 pp.

Borba, B. M. and H. H. Hamner. 1996. Subsistence and personal use salmon harvest estimates, Yukon Area, 1995. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A96-28, Anchorage, Alaska.

Borba, B. M. and H. H. Hamner. 1997. Subsistence and personal use salmon harvest estimates, Yukon Area, 1996. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A97-28, Anchorage, Alaska.

Borba, B. M. and H. H. Hamner. 1998. Subsistence and personal use salmon harvest estimates, Yukon Area, 1997. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A98-23, Anchorage, Alaska.

Borba, B. M. and H. H. Hamner. 1999. Subsistence and personal use salmon harvest estimates, Yukon Area, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A99-27, Anchorage, Alaska.

Borba, B. M. and H. H. Hamner. 2000. Subsistence and personal use salmon harvest estimates, Yukon Area, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A00-23, Anchorage, Alaska.

Buklis, L. S. 1993. Documentation of Arctic-Yukon-Kuskokwim Region Salmon Escapement Goals in Effect as of the 1992 Fishing Season. Regional Informational Report No. 3A93-03, Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region, 333 Raspberry Road, Anchorage, AK 99518. 60 pp.

Cappiello, T. A. and J. F. Bromaghin. 1995. Mark-recapture abundance estimate of fall-run chum salmon in the upper Tanana River, Alaska, 1995. Alaska Department of Fish and Game, Alaska Fisheries Research Bulletin. 4(1):12-35. 1997.

Cappiello, T. A. and D. L. Bruden. 1997. Mark-recapture abundance estimate of fall-run chum salmon in the upper Tanana River, Alaska, 1996. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A97-37. Anchorage, Alaska.

Chinook Technical Committee (CTC). 1999. Maximum sustained yield of biologically based escapement goals for selected chinook salmon stocks used by the Pacific Salmon Commission's Chinook Technical Committee for escapement assessment, Volume I. Pacific Salmon Commission Joint Chinook Technical Committee Report No. TCCHINOOK (99)-3, Vancouver, British Columbia, Canada.

Cleary, P. M. and D. A. Bruden. 2000. Estimation of fall chum salmon abundance on the upper Tanana River using mark-recapture techniques, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A00-03. Anchorage, Alaska.

Daum, D. W. and B. W. Osborn. 1996. Enumeration of Chandalar River fall chum salmon using split-beam sonar, 1995. U.S. Fish and Wildlife Service, Fishery Resource Office, Alaska Fisheries Progress Report 96-2, Fairbanks, Alaska.

Daum, D. W. and B. W. Osborn. 1998A. Enumeration of Chandalar River fall chum salmon using split-beam sonar, 1996. U.S. Fish and Wildlife Service, Fishery Resource Office, Alaska Fisheries Progress Technical Report 47, Fairbanks, Alaska.

Daum, D. W. and B. W. Osborn. 1998B. Use of fixed-location, split-beam sonar to describe temporal and spatial patterns of adult fall chum salmon migration in the Chandalar River, Alaska. N. J. Fish. Manage. 18:477-486.

Daum, D. W. and B. W. Osborn. 2000. Enumeration of Chandalar River fall chum salmon using split-beam sonar, 1997. U.S. Fish and Wildlife Service, Fishery Resource Office, Alaska Fisheries Progress Technical Report 56, Fairbanks, Alaska.

Efron, B. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York.

Gordon, J. A., S. P. Klosiewski, T. J. Underwood, and R. J. Brown. 1998. Estimated abundance of adult fall chum salmon in the upper Yukon River, Alaska, 1996. U.S. Fish and Wildlife Service, Fairbanks Fishery Resource Office, Alaska Fisheries Technical Report No. 45, Fairbanks, Alaska

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment. Chapman and Hall. New York.

Hebert, K. P. and D. L. Bruden. 1998. Mark-recapture population size estimate of fall chum salmon in the upper Tanana River, 1997. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A98-21. Anchorage, Alaska

Holder, R. R. and H. H. Hamner. 1995. Estimates of subsistence salmon harvests within the Yukon River drainage in Alaska 1992. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Technical Fishery Report 95-07, Anchorage, Alaska.

Holder, R. R. and H. H. Hamner. 1998a. Estimates of subsistence salmon harvests within the Yukon River drainage in Alaska 1993. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A98-06, Anchorage, Alaska.

Holder, R. R. and H. H. Hamner. 1998b. Estimates of subsistence salmon harvests within the Yukon River drainage in Alaska 1994. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 3A98-20, Anchorage, Alaska.

Noakes, D., D. W. Welch, and M. Stocker. 1987. A time series approach to stock-recruitment analysis: transfer function noise modeling. Natural Resource Modeling 2:213-233.

Pankratz, A. 1991. Forecasting with dynamic regression models. John Wiley. New York.

Ricker, W.E. 1954. Stock and Recruitment. J. Fish. Res. Bd. Can. 11:559-623.

Ricker, W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada No. 191. 382 pp.

Seeb, L.W., and P. A. Crane. 1999. High genetic heterogeneity in chum salmon in western Alaska and the contact zone between northern and southern lineages. Trans. Am. Fish. Soc. 128:58-87.

Underwood, T. J., S. P. Klosiewski, J. A. Gordon, J. L. Melegari, and R. J. Brown. 2000. Estimated abundance of adult fall Chum salmon in the upper Yukon River, Alaska, 1997. U.S. Fish and Wildlife Service, Fairbanks Fishery Resource Office, Alaska Fisheries Technical Report No. 56, Fairbanks, Alaska.

Table 1. Historical escapement of fall chum salmon in the Tanana River. Figures in bold italics were estimated, see text for methods.

Year	Toklat River	Delta River	Upper Tanana River	Tanana River
1974	41,798	5,915	***48,177***	***89,975***
1975	92,265	3,734	***30,413***	***122,678***
1976	52,891	6,312	***51,411***	***104,302***
1977	34,887	16,876	***137,454***	***172,341***
1978	37,001	11,136	***90,702***	***127,703***
1979	158,336	8,355	***68,051***	***226,387***
1980	26,346	5,137	***41,841***	***68,187***
1981	15,623	23,508	***191,471***	***207,094***
1982	3,624	4,235	***34,494***	***38,118***
1983	21,869	7,705	***62,757***	***84,626***
1984	16,758	12,411	***101,087***	***117,845***
1985	22,750	17,276	***140,712***	***163,462***
1986	17,976	6,703	***54,596***	***72,572***
1987	22,117	21,180	***172,510***	***194,627***
1988	13,436	18,024	***146,804***	***160,240***
1989	30,421	21,342	***173,829***	***204,250***
1990	34,739	8,992	***73,239***	***107,978***
1991	13,347	32,905	***268,009***	***281,356***
1992	14,070	8,893	***72,433***	***86,503***
1993	27,838	19,857	***161,734***	***189,572***
1994	76,057	23,777	***193,662***	**269,719**
1995	54,513	20,587	268,173	322,686
1996	18,264	19,758	134,563	152,827
1997	14,511	7,705	71,661	86,172
1998	15,605	7,804	62,384	77,989
1999	4,551	16,534	104,869	109,420
Average, 1974-1999	33,907	13,718	113,732	147,640
Average, 1980-1999	23,221	15,217	126,541	149,762
Minimum	3,624	3,734	30,413	38,118
Maximum	158,336	32,905	268,173	322,686

Table 2. Retrospective performance of estimating Upper Tanana River Escapement based on expansion of Delta River escapement by 8.13 (= 1/0.123).

Year	Delta River Escapement	Upper Tanana River Escapement	Delta as Percent of Upper Tanana	Predicted Upper Tanana Escapement Based on Expansion of Delta River Escapement	Absolute Percent Error	Absolute Error
1995	20,587	268,173	7.7%	167,680	37.5%	62,835
1996	19,758	134,563	14.7%	160,928	19.6%	31,530
1997	7,705	71,661	10.8%	62,757	12.4%	7,798
1998	7,804	62,384	12.5%	63,563	1.9%	1,201
1999	16,534	104,869	15.8%	134,668	28.4%	38,267
Average 1995 - 1999			12.3%		20.0%	28,326

Table 3. Historical escapement of fall chum salmon in the Upper Yukon River Tributaries. Figures in bold italics were estimated, see text for methods.

Year	Chandalar River	Sheenjek River	Fishing Branch River	Upper Yukon River Tributaries
1974	***129,685***	117,921	32,525	***280,131***
1975	***501,011***	227,935	353,282	***1,082,228***
1976	***61,403***	34,649	36,584	***132,636***
1977	***127,816***	59,878	88,400	***276,094***
1978	***71,944***	42,661	40,800	***155,405***
1979	***206,904***	120,129	119,898	***446,931***
1980	***78,707***	36,039	55,268	***170,014***
1981	***137,509***	102,137	57,386	***297,032***
1982	***50,809***	43,042	15,901	***109,752***
1983	***79,467***	64,989	27,200	***171,656***
1984	***44,241***	36,173	15,150	***95,564***
1985	***203,211***	179,727	56,016	***438,954***
1986	***99,932***	84,207	31,723	***215,862***
1987	***174,317***	153,267	48,956	***376,540***
1988	***59,308***	45,206	23,597	***128,111***
1989	***123,223***	99,116	43,834	***266,173***
1990	***97,191***	77,750	35,000	***209,941***
1991	***107,086***	86,496	37,733	***231,315***
1992	***87,343***	78,808	22,517	***188,668***
1993	***61,744***	42,922	28,707	***133,373***
1994	***186,031***	150,565	65,247	***401,843***
1995	280,999	241,855	51,971	574,825
1996	208,170	246,889	77,278	532,337
1997	199,874	80,423	26,959	307,256
1998	75,811	33,058	13,248	122,117
1999	88,662	14,229	12,904	115,795
Average, 1974-1999	136,246	96,157	54,542	286,944
Average, 1980-1999	122,182	94,845	37,330	254,356
Minimum	44,241	14,229	12,904	95,564
Maximum	501,011	246,889	353,282	1,082,228

Table 4. Retrospective performance of estimating Upper Yukon River Tributary escapement based on expansion of collective Sheenjek/Fishing Branch River escapement by 1.86. The expansion factor estimated by linear regression.

Year	Chandalar River	Sheenjek River	Fishing Branch River	Upper Yukon Tributaries	Predicted Upper Yukon River Tributary Escapement Based on Expansion of Sheenjek/Fishing Branch River Escapement	Absolute Percent Error	Absolute Error
1995	280,999	241,855	51,971	574,825	547,105	5.1%	27,720
1996	208,170	246,889	77,278	532,337	603,600	11.8%	71,263
1997	199,874	80,423	26,959	307,256	199,946	53.7%	107,310
1998	75,811	33,058	13,248	122,117	86,222	41.6%	35,895
1999	88,662	14,229	12,904	115,795	50,522	129.2%	65,273
Average 1995-1999						48.3%	61,492

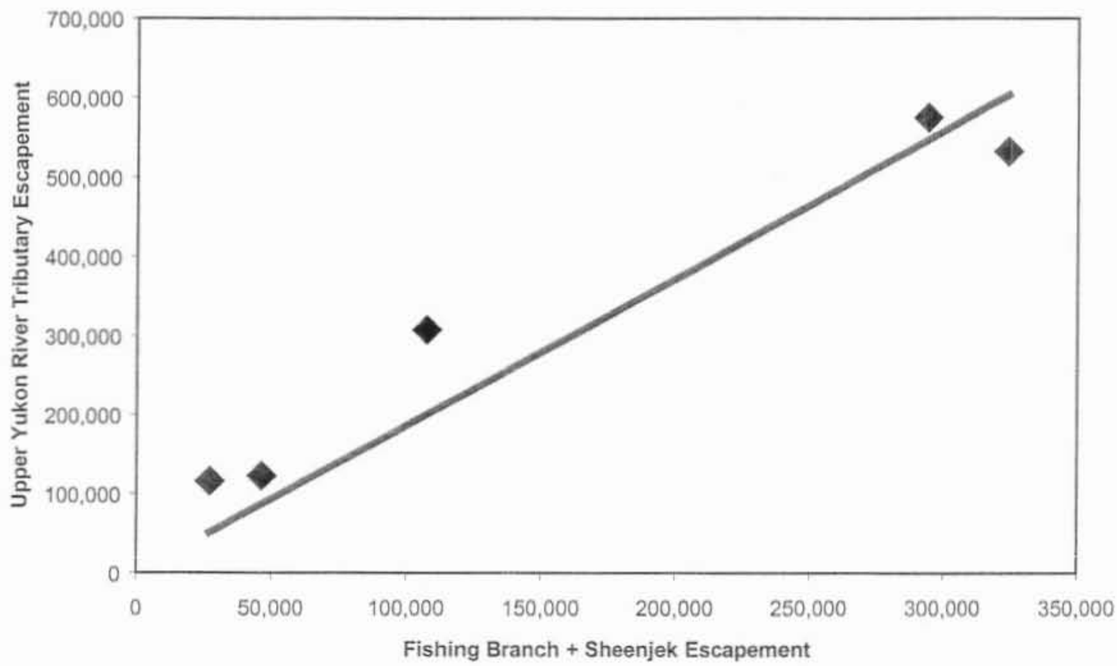


Table 5. Historical escapement of fall chum salmon in the Upper Yukon River mainstem. Figures in bold italics were estimated, see text for methods.

Year	Upper Yukon River Tributaries	Upper Yukon River Mainstem	Upper Yukon River
1974	280,131	***67,379***	***347,511***
1975	1,082,228	***260,307***	***1,342,535***
1976	132,636	***31,903***	***164,539***
1977	276,094	***66,408***	***342,503***
1978	155,405	***37,379***	***192,784***
1979	446,931	***107,500***	***554,431***
1980	170,014	22,912	192,926
1981	297,032	47,066	344,098
1982	109,752	31,958	141,710
1983	171,656	90,875	262,531
1984	95,564	56,633	152,197
1985	438,954	62,010	500,964
1986	215,862	87,940	303,802
1987	376,540	80,776	457,316
1988	128,111	36,786	164,897
1989	266,173	35,750	301,923
1990	209,941	51,735	261,676
1991	231,315	78,461	309,776
1992	188,668	49,082	237,750
1993	133,373	29,743	163,116
1994	401,843	98,358	500,201
1995	574,825	158,092	732,917
1996	532,337	122,429	654,766
1997	307,256	85,439	392,695
1998	122,117	46,305	168,422
1999	115,795	65,896	181,691
Average, 1974-1999	286,944	73,428	360,372
Average, 1980-1999	254,356	66,912	321,269
Minimum	95,564	22,912	141,710
Maximum	1,082,228	260,307	1,342,535

Table 6. Retrospective performance of estimating Total Upper Yukon River Escapement based on expansion of collective Sheenjek and Fishing Branch Rivers escapement by 2.31. The expansion factor estimated by linear regression.

Year	Sheenjek River Escapement	Fishing Branch River Escapement	Total Upper Yukon River Escapement	Sheenjek/Fishing Branch Rivers as Percent of Upper Yukon	Predicted Upper Yukon based on expansion of Sheenjek/Fishing Branch Rivers	Absolute Percent Error	Absolute Error
1980	36,039	55,268	192,926	47.3%	210,907	9.3%	17,981
1981	102,137	57,386	344,098	46.4%	368,477	7.1%	24,379
1982	43,042	15,901	141,710	41.6%	136,151	3.9%	5,560
1983	64,989	27,200	262,531	35.1%	212,944	18.9%	49,587
1984	36,173	15,150	152,197	33.7%	118,549	22.1%	33,647
1985	179,727	56,016	500,964	47.1%	544,535	8.7%	43,571
1986	84,207	31,723	303,802	38.2%	267,783	11.9%	36,019
1987	153,267	48,956	457,316	44.2%	467,109	2.1%	9,793
1988	45,206	23,597	164,897	41.7%	158,926	3.6%	5,972
1989	99,116	43,834	301,923	47.3%	330,196	9.4%	28,272
1990	77,750	35,000	261,676	43.1%	260,438	0.5%	1,238
1991	86,496	37,733	309,776	40.1%	286,953	7.4%	22,823
1992	78,808	22,517	237,750	42.6%	234,047	1.6%	3,702
1993	42,922	28,707	163,116	43.9%	165,454	1.4%	2,337
1994	150,565	65,247	500,201	43.1%	498,497	0.3%	1,703
1995	241,855	51,971	732,917	40.1%	678,699	7.4%	54,218
1996	246,889	77,278	654,766	49.5%	748,783	14.4%	94,017
1997	80,423	26,959	392,695	27.3%	248,038	36.8%	144,657
1998	33,058	13,248	168,422	27.5%	106,961	36.5%	61,461
1999	14,229	12,904	181,691	14.9%	62,674	65.5%	119,017
Average 1980 - 1999				39.7%		13.4%	37,997

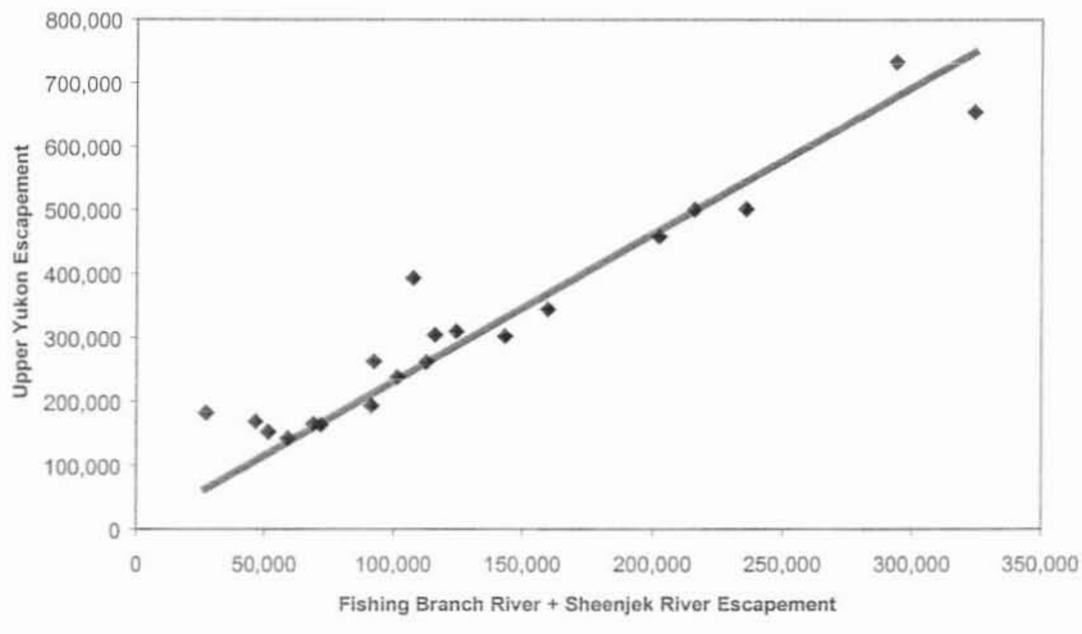


Table 7. Fall chum salmon total utilization in numbers of fish, Yukon River drainage, District 1 – 3, 1961 - 1999. Figures in bold text were estimated.[a]

	District 1					District 2				District 3		
Year	Sub-sistence	Com-mercial[b]	Personal Use	Test Fish	Total	Sub-sistence	Com-mercial[b]	Test Fish	Total	Sub-sistence	Com-mercial	Total
1974	**11,022**	176,036			187,058	**11,893**	53,540		65,433	**2,376**	552	2,928
1975	**11,022**	158,183			169,205	**11,893**	51,666		63,559	**2,376**	5,590	7,966
1976	**11,022**	105,851			116,873	**11,893**	21,212		33,105	**2,376**	4,250	6,626
1977	**11,022**	131,758			142,780	**11,893**	51,994		63,887	**2,376**	15,851	18,227
1978	**11,022**	127,947			138,969	**11,893**	51,646		63,539	**2,376**	11,527	13,903
1979	15,788	109,406			125,194	14,662	94,042		108,704	2,443	25,955	28,398
1980	7,433	106,829			114,262	12,435	83,881		96,316	2,320	13,519	15,839
1981	15,540	167,834			183,374	11,770	154,883		166,653	3,043	19,043	22,086
1982	10,016	97,484			107,500	9,511	96,581		106,092	1,659	5,815	7,474
1983	8,238	124,371			132,609	10,341	85,645		95,986	2,863	10,018	12,881
1984	8,885	78,751			87,636	11,394	70,803		82,197	2,233	6,429	8,662
1985	13,275	129,948			143,223	11,544	40,490		52,034	2,290	5,164	7,454
1986	9,000	59,352			68,352	13,483	51,307		64,790	2,155	2,793	4,948
1987	18,467	0	0		18,467	13,454	0		13,454	3,287	0	3,287
1988	5,475	44,890	5	639	51,009	8,600	31,845	16	40,461	1,747	2,090	3,837
1989	4,914	74,235	18	3,641	82,808	10,015	97,558	348	107,921	1,023	15,332	16,355
1990	5,335	25,269	60	2,068	32,732	6,187	37,077	96	43,360	2,056	3,715	5,771
1991	3,935	59,724	-	2,455	66,114	5,628	102,628	96	108,352	615	9,213	9,828
1992	5,216	0	-	0	5,216	7,382	0	0	7,382	2,358	0	2,358
1993	7,770	0	-	0	7,770	3,094	0	0	3,094	1,449	0	1,449
1994	4,887	0	-	0	4,887	4,151	0	0	4,151	862	0	862
1995	4,698	79,345	-	1,121	85,164	3,317	90,831	0	94,148	1,672	0	1,672
1996	4,147	33,629	-	1,717	39,493	5,287	29,651	0	34,938	2,706	0	2,706
1997	3,132	27,483	-	867	31,482	4,680	24,326	0	29,006	787	0	787
1998	3,163	0	-	0	3,163	4,482	0	0	4,482	1,561	0	1,561
1999	6,502	9,987	-	1,149	17,638	4,594	9,703	22	14,319	415	0	415

a Subsistence harvest estimates not available by district until 1978. Subsistence harvests 1974 - 1978, were estimated as the average subsistence harvest, 1979 - 1986 for the respective districts.

b Includes department test fish sales prior to 1988.

Table 8. Fall chum salmon total utilization in numbers of fish, Yukon River drainage, District 4 – 6, 1961-1999.[a]

	District 4				District 5					District 6					
Year	Sub-sistence [c]	Com-mercial	Com-mercial Related [d]	Total	Sub-sistence [c]	Com-mercial	Com-mercial Related [d]	Per-sonal Use	Total	Sub-sistence [c]	Com-mercial	Com-mercial Related [d]	Per-sonal Use	Test Fish	Total
1974	**25,362**	9,213	0	34,575	**95,411**	23,551	0		118,962	**31,390**	26,884	0			58,274
1975	**25,362**	13,666	0	39,028	**95,411**	27,212	0		122,623	**31,390**	18,692	0			50,082
1976	**25,362**	1,742	0	27,104	**95,411**	5,387	0		100,798	**31,390**	17,948	0			49,338
1977	**25,362**	13,980	0	39,342	**95,411**	25,730	0		121,141	**31,390**	18,673	0			50,063
1978	**25,362**	10,988	1,721	38,071	**95,411**	21,016	5,220		121,647	**31,390**	13,259	3,687			48,336
1979	34,697	48,899	3,199	86,795	102,695	47,459	8,097		158,251	44,596	34,185	7,170			85,951
1980	19,328	27,978	4,347	51,653	75,861	41,771	605		118,237	50,260	19,452	68			69,780
1981	18,662	12,082	1,311	32,055	104,612	86,620	6,955		198,187	23,613	25,989	3,019			52,621
1982	20,152	3,894	167	24,213	71,786	13,593	42		85,421	18,968	6,820	596			26,384
1983	32,246	4,482	1,963	38,691	105,103	43,993	0		149,096	29,073	34,089	3,101			66,263
1984	28,937	7,625	2,215	38,777	98,376	24,060	57		122,493	22,670	20,564	56			43,290
1985	22,750	24,452	2,525	49,727	117,125	25,338	0		142,463	36,963	42,352	0			79,315
1986	26,126	2,045	0	28,171	87,729	22,053	395		110,177	24,973	1,892	182			27,047
1987	41,467	0	0	41,467	141,335 e	0	0	15,750	157,085	124,587 f	0	0	3,316		127,903
1988	16,958	15,662	1,421	34,041	84,209	16,989	0	1,762	102,960	34,597	21,844	1,806	2,114	27,008	87,369
1989	24,540	11,776	3,407	39,723	112,001	18,215	3,989	3,294	137,499	58,654	49,090	7,353	1,770	16,984	133,851
1990	19,241	4,989	3,177	27,407	90,513	7,778	1,198	3,723	103,212	44,568	43,182	7,793	1,393	7,060	103,996
1991	20,875	3,737	2,354	26,966	74,002	27,355	4,759	-	106,116	40,469	28,195	16,253	0	1,385	86,302
1992	21,232	0	0	21,232	45,701	0	0	-	45,701	25,713	15,721	3,301	0	1,407	46,142
1993	10,832	0	0	10,832	43,764	0	0	-	43,764	9,853	0	0	163	0	10,016
1994	13,325	0	0	13,325	66,396	3,630	0	-	70,026	33,597	1	4,368	0	0	37,966
1995	14,057	2,924	5,807	22,788	57,594	9,778	20,255	-	87,627	49,168	67,855	6,262	863	0	124,148
1996	16,786	2,918	0	19,704	63,473	11,878	9,980	-	85,331	36,467	10,266	7,308	356	0	54,397
1997	11,734	2,458	0	14,192	55,258	2,446	1,474	-	59,178	19,550	0	0	284	0	19,834
1998	7,898	0	0	7,898	31,393	0	0	-	31,393	14,370	0	0	2	0	14,372
1999	9,174	681	0	9,855	53,580	0	0	-	53,580	15,471	0	0	262	0	15,733

a Subsistence harvest estimates not available by district until 1978. Subsistence harvests 1974 - 1978, were estimated as the average subsistence harvest, 1979 - 1986 for the respective districts.

b Includes department test fish sales prior to 1988.

c From 1978 through 1988, the commercial-related harvest was subtracted from the subsistence harvest in Districts 4, 5 and 6 because it was assumed that this harvest was included in the reported subsistence harvest during that time period. Beginning in 1989, subsistence surveys attempted to document subsistence only fishing harvests and commercial related harvests separately.

d In Districts 4, 5 and 6, commercial related refers to the estimated number of females harvested to produce roe sold.

e Includes an estimated 95,768 fall chum salmon illegally sold in District 5.

f Includes an estimated 119,168 fall chum salmon illegally sold in District 6.

Table 9. Fall chum salmon total utilization in numbers of fish, Alaskan and Canadian Areas of the Yukon River drainage, 1961-1999.

	Alaska Yukon Area Totals						Canadian Area Totals					
								Mainstem Yukon River				
Year	Sub-sistence	Com-mercial	Com-mercial Related	Personal Use	ADF&G Test Fish	Total	Old Crow Ab-original	Ab-original	Domestic	Com-mercial	Subtotal	Total
1974	**177,453**	289,776	0			467,229	7,000	1,636	466	2,544	4,646	11,646
1975	**177,453**	275,009	0			452,462	11,000	2,500	4,600	2,500	9,600	20,600
1976	**177,453**	156,390	0			333,843	3,100	100	1,000	1,000	2,100	5,200
1977	**177,453**	257,986	0			435,439	5,560	1,430	1,499	3,990	6,919	12,479
1978	**177,453**	236,383	10,628			424,464	5,000	482	728	3,356	4,566	9,566
1979	214,881	359,946	18,466			593,293		11,000	2,000	9,084	22,084	22,084
1980	167,637	293,430	5,020			466,087	6,000	3,218	4,000	9,000	16,218	22,218
1981	177,240	466,451	11,285			654,976	3,000	2,410	1,611	15,260	19,281	22,281
1982	132,092	224,187	805			357,084	1,000	3,096	683	11,312	15,091	16,091
1983	187,864	302,598	5,064			495,526	2,000	1,200	300	25,990	27,490	29,490
1984	172,495	208,232	2,328			383,055	4,000	1,800	535	22,932	25,267	29,267
1985	203,947	267,744	2,525			474,216	3,500	1,740	279	35,746	37,765	41,265
1986	163,466	139,442	577			303,485	657	2,200	222	11,464	13,886	14,543
1987	342,597	0	0	19,066		361,663	135	3,622	132	40,591	44,345	44,480
1988	151,586	133,320	3,227	3,881	27,663	319,677	1,071	1,882	349	30,263	32,494	33,565
1989	211,147	266,206	14,749	5,082	20,973	518,157	2,909	2,462	100	17,549	20,111	23,020
1990	167,900	122,010	12,168	5,176	9,224	316,478	2,410	3,675	0	27,537	31,212	33,622
1991	145,524	230,852	23,366	0	3,936	403,678	1,576	2,438	0	31,404	33,842	35,418
1992	107,602	15,721	3,301	0	1,407	128,031	1,935	304	0	18,576	18,880	20,815
1993	76,762	0	0	163	0	76,925	1,668	4,660	0	7,762	12,422	14,090
1994	123,218	3,631	4,368	0	0	131,217	2,654	5,319	0	30,035	35,354	38,008
1995	130,506	250,733	32,324	863	1,121	415,547	5,489	1,099	0	39,012	40,111	45,600
1996	128,866	88,342	17,288	356	1,717	236,569	3,025	1,260	0	20,069	21,329	24,354
1997	95,141	56,713	1,474	284	867	154,479	6,294	1,218	0	8,068	9,286	15,580
1998	62,867	0	0	2	0	62,869	6,159	1,745	0	0	1,745	7,904
1999	89,736	20,371	0	262	1,171	111,540	6,000	3,172	0	10,402	13,574	19,574

Table 10. Annual age composition estimates of the Yukon River fall chum salmon run, 1977–1999 at the mouth of the Yukon River.

Year	Age 3	Age 4	Age 5	Age 6
1977 [a]	9.5%	85.1%	5.3%	0.1%
1978 [a]	19.9%	66.0%	13.9%	0.2%
1979 [a]	7.3%	87.8%	4.9%	0.0%
1980 [a]	13.7%	78.2%	8.2%	0.0%
1981 [b]	1.8%	87.1%	11.1%	0.0%
1982 [b]	7.4%	60.0%	31.8%	0.8%
1983 [c]	1.0%	88.2%	10.4%	0.5%
1984 [c]	6.7%	53.1%	40.2%	0.0%
1985 [c]	1.0%	81.0%	17.7%	0.3%
1986 [c]	1.8%	57.7%	40.1%	0.4%
1987 [c]	0.7%	82.7%	15.8%	0.8%
1988 [c]	6.9%	60.1%	32.9%	0.1%
1989 [c]	0.0%	83.2%	16.6%	0.2%
1990 [c]	1.7%	59.6%	37.6%	1.2%
1991 [c]	4.0%	59.9%	35.8%	0.3%
1992 [c]	0.6%	37.0%	61.5%	0.9%
1993 [c]	0.2%	63.8%	34.3%	1.7%
1994 [d]	0.4%	61.7%	36.8%	1.2%
1995 [c]	0.5%	69.7%	28.5%	1.4%
1996 [c]	0.8%	62.5%	33.8%	2.9%
1997 [c]	0.7%	67.4%	30.1%	1.8%
1998 [c]	0.7%	67.4%	30.5%	1.3%
1999 [c]	0.2%	59.4%	38.7%	1.7%

[a]Annual age composition estimates based on District 1 Commercial gill net samples (6 " mesh).

[b]Annual age composition estimates based ADF&G test fishery harvests from 6 " mesh gillnets at the Big Eddy and Middle Mouth sites. Samples weighted by test fish CPUE. Commercial fishery samples used for time periods when test fishery samples were not available.

[c]Annual age composition estimates based ADF&G test fishery harvests from 6 " mesh gillnets at the Big Eddy and Middle Mouth sites. Samples weighted by test fish CPUE.

[d]The lower river test fishery was terminated early in 1994. Estimates of age composition based on extension of age specific abundances based on age specific run timing curves estimated from prior years.

Table 11. Subsistence and personal use harvest of fall chum salmon, in District 5 and tributaries above the Tanana River, 1990 to 1995. Harvests are aggregated into areas, mainstem Yukon River below Tanana, mainstem Yukon River from Tanana to Porcupine River, mainstem Yukon River from the Porcupine River to the U.S./Canada border, and the Chandalar/Porcupine Rivers.

	1990		1991		1992		1993		1994		1995	
Village	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Tanana	41,145		40,868		19,365		23,103		34,681		14,409	
Commercial–related											20,120	
Y5 below Rampart	41,145	43.7%	40,868	55.2%	19,365	42.4%	23,103	52.8%	34,681	52.2%	34,529	44.4%
Rampart	10,818		5,801		5,701		3,272		1,007		1,403	
Fairbanks Subs., Personal Use	4,174		2,022		2,491		930		2,870		2,184	
Stevens Village	3,857		2,481		150		862		45		3,194	
Beaver	757		7		361		692		2,069		1,231	
Fort Yukon	5,814		3,734		1,142		1,190		3,414		4,598	
Y5 Tanana to Porcupine	25,420	27.0%	14,045	19.0%	9,845	21.5%	6,946	15.9%	9,405	14.2%	12,610	16.2%
Fort Yukon	5,814		3,734		1,142		1,190		3,414		4,598	
Central	165		73		100		0		0		0	
Circle	6,639		6,340		6,279		349		4,581		5,102	
Eagle	8,027		7,985		5,630		2,070		8,263		13,115	
Other	160		100		0		1,750		0		830	
Yukon Above Porcupine	20,805	22.1%	18,232	24.6%	13,151	28.8%	5,359	12.2%	16,258	24.5%	23,645	30.4%
Venetie	5,377		758		3,066		7,881		4,302		6,085	
Chalkyitsik	1,490		100		274		475		1,751		845	
Chandalar/Porcupine	6,867	7.3%	858	1.2%	3,340	7.3%	8,356	19.1%	6,053	9.1%	6,930	8.9%
Total Catch	94,237		74,002		45,701		43,764		66,396		77,714	

Table 11. (continued). Subsistence and personal use harvest of fall chum salmon, in District 5 and tributaries above the Tanana River, 1996 to 1999. Harvests are aggregated into areas, mainstem Yukon River below Tanana, mainstem Yukon River from Tanana to Porcupine River, mainstem Yukon River from the Porcupine River to the U.S./Canada border, and the Chandalar/Porcupine Rivers.

	1996		1997		1998		1999		1990-1999
Village	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	Average
Tanana	21,420		25,058		24,956		22,305		
Commercial-related	15,463								
Y5 below Rampart	36,883	46.7%	25,058	45.3%	24,956	79.5%	22,305	41.6%	50.4%
Rampart	896		646		100		4,324		
Fairbanks Subs., Personal Use	2,727		491		96		681		
Stevens Village	991		1,585		1,076		20		
Beaver	9		243		409		16		
Fort Yukon	4,072		3,060		1,518		4,851		
Y5, Tanana to Porcupine	8,695	11.0%	6,025	10.9%	3,199	10.2%	9,892	18.5%	16.4%
Fort Yukon	4,072		3,060		1,518		4,851		
Central	132		0		0		0		
Circle	5,308		3,707		37		2,722		
Eagle	14,916		14,488		543		11,292		
Other	505		421		50		65		
Yukon Above Porcupine	24,933	31.6%	21,676	39.2%	2,148	6.8%	18,930	35.3%	25.6%
Venetie	7,195		1,564		658		2,011		
Chalkyitsik	1,230		936		433		442		
Chandalar/Porcupine	8,425	10.7%	2,500	4.5%	1,091	3.5%	2,453	4.6%	7.6%
Total Catch	78,936		55,258		31,393		53,580		

Table 12. Yukon River fall chum salmon total utilization aggregated by districts and areas within District 5 appropriate for stock specific run reconstruction, 1974-1999.

			District 5					
Year	Districts 1-4	District 6	Below[a] Tanana	Tanana to Porcupine[b]	Upper Yukon Tributaries[c]	Above Porcupine[d]	Canadian Mainstem	Total Yukon River Catch
1974	289,993	58,274	**59,946**	**19,548**	16,057	30,410	4,646	478,875
1975	279,757	50,082	**61,791**	**20,150**	20,336	31,346	9,600	473,062
1976	183,707	49,338	**50,793**	**16,564**	10,774	25,767	2,100	339,043
1977	264,235	50,063	**61,044**	**19,907**	14,783	30,967	6,919	447,918
1978	254,481	48,336	**61,299**	**19,990**	14,261	31,097	4,566	434,030
1979	349,091	85,951	**79,745**	**26,005**	12,048	40,454	22,084	615,377
1980	278,070	69,780	59,581	19,429	15,002	30,225	16,218	488,305
1981	404,168	52,621	99,869	32,567	18,089	50,663	19,281	677,257
1982	245,279	26,384	43,045	14,037	7,503	21,836	15,091	373,175
1983	280,167	66,263	75,131	24,500	13,351	38,113	27,490	525,016
1984	217,272	43,290	61,726	20,129	13,326	31,313	25,267	412,322
1985	252,438	79,315	71,789	23,410	14,346	36,418	37,765	515,481
1986	166,261	27,047	55,519	18,105	9,045	28,165	13,886	318,028
1987	76,675	127,903	79,157	25,813	12,094	40,156	44,345	406,143
1988	129,348	87,369	51,883	16,919	8,910	26,320	32,494	353,242
1989	246,807	133,851	69,287	22,595	13,377	35,149	20,111	541,177
1990	109,270	103,996	52,010	16,960	10,268	26,384	31,212	350,100
1991	211,260	86,302	53,473	17,438	9,655	27,126	33,842	439,096
1992	36,188	46,142	19,954	12,328	5,265	10,090	18,880	148,846
1993	23,145	10,016	24,169	8,306	2,175	10,782	12,422	91,015
1994	23,225	37,966	29,672	15,085	7,772	20,151	35,354	169,225
1995	203,772	124,148	46,258	13,908	22,220	10,730	40,111	461,147
1996	96,841	54,397	44,571	12,087	10,804	20,894	21,329	260,923
1997	75,467	19,834	26,293	9,602	11,571	18,005	9,286	170,059
1998	17,104	14,372	14,668	3,458	9,510	9,916	1,745	70,773
1999	42,227	15,733	24,297	5,842	8,424	21,017	13,574	131,114

[a]District 5 harvest below Tanana, 1974-1989, based on the average proportion of District 5 subsistence catch from Tanana Village, ($average_{1990\text{-}1999} = 0.504$).

[b]District 5 harvest Tanana to Porcupine, 1974-1989, based on the average proportion of subsistence harvest in that area ($average_{1990\text{-}1999} = 0.164$).

[c]District 5 harvest in Upper Yukon tributaries, 1974-1989, based on the average proportion of District 5 subsistence harvest in that area ($average_{1990\text{-}1999} = 0.076$). Also includes Canadian harvest in Porcupine River.

[d]District 5 harvest above the Porcupine River, 1974-1989, based on the average proportion of District 5 subsistence harvest in that area ($average_{1990\text{-}1999} = 0.256$).

Table 13. Reconstructed Yukon fall chum salmon run by stock at the mouth of the Porcupine River, 1974-1999.

	Stock Composition of the In-river Yukon Run at the Mouth of the Porcupine River		In-river Run at the Mouth of the Porcupine River		
Year	Upper Yukon Tributaries	Upper Yukon Mainstem	Upper Yukon Tributaries	Upper Yukon Mainstem	Total Run
1974	74.3%	25.7%	296,188	102,436	398,624
1975	78.5%	21.5%	1,102,564	301,253	1,403,817
1976	70.6%	29.4%	143,410	59,770	203,180
1977	73.6%	26.4%	290,877	104,295	395,172
1978	69.9%	30.1%	169,666	73,042	242,708
1979	73.0%	27.0%	458,979	170,037	629,017
1980	72.7%	27.3%	185,016	69,355	254,371
1981	72.9%	27.1%	315,121	117,010	432,131
1982	63.0%	37.0%	117,255	68,885	186,141
1983	54.2%	45.8%	185,007	156,478	341,486
1984	49.0%	51.0%	108,889	113,213	222,102
1985	76.9%	23.1%	453,301	136,193	589,493
1986	63.4%	36.6%	224,907	129,991	354,898
1987	70.2%	29.8%	388,634	165,277	553,911
1988	58.9%	41.1%	137,021	95,600	232,621
1989	75.4%	24.6%	279,551	91,010	370,561
1990	66.8%	33.2%	220,209	109,331	329,540
1991	63.3%	36.7%	240,970	139,429	380,399
1992	71.3%	28.7%	193,933	78,052	271,984
1993	71.9%	28.1%	135,549	52,947	188,496
1994	72.7%	27.3%	409,615	153,863	563,477
1995	74.1%	25.9%	597,045	208,933	805,978
1996	76.7%	23.3%	543,141	164,652	707,793
1997	73.9%	26.1%	318,827	112,730	431,557
1998	69.4%	30.6%	131,627	57,966	189,593
1999	55.3%	44.7%	124,219	100,487	224,706

Table 14. Reconstructed Yukon fall chum salmon run by stock at the mouth of the Tanana River, 1974-1999.

	Stock Composition of In-river Run at the Mouth of the Tanana River			In-river Run at the Mouth of the Tanana River				Y5 Utilization, Tanana River to Porcupine River	
Year	Tanana River	Upper Yukon Tributaries	Upper Yukon Mainstem	Tanana River	Upper Yukon Tributaries	Upper Yukon Mainstem	Total Run	Upper Yukon Tributaries	Upper Yukon Mainstem
1974	26.2%	54.9%	19.0%	148,249	310,713	107,459	566,421	14,525	5,023
1975	10.8%	70.0%	19.1%	172,760	1,118,390	305,577	1,596,726	15,826	4,324
1976	41.1%	41.5%	17.3%	153,639	155,101	64,642	373,383	11,691	4,873
1977	34.9%	47.9%	17.2%	222,403	305,530	109,548	637,482	14,653	5,254
1978	40.1%	41.9%	18.0%	176,039	183,640	79,058	438,736	13,974	6,016
1979	32.3%	49.4%	18.3%	312,338	477,954	177,067	967,359	18,975	7,030
1980	33.5%	48.4%	18.1%	137,967	199,148	74,652	411,767	14,132	5,297
1981	35.9%	46.8%	17.4%	259,715	338,870	125,828	724,413	23,749	8,818
1982	24.4%	47.6%	28.0%	64,502	126,098	74,080	264,679	8,842	5,195
1983	29.2%	38.4%	32.4%	150,889	198,281	167,705	516,875	13,274	11,227
1984	39.9%	29.4%	30.6%	161,135	118,758	123,473	403,366	9,868	10,260
1985	28.4%	55.1%	16.5%	242,777	471,302	141,601	855,681	18,002	5,409
1986	21.1%	50.0%	28.9%	99,619	236,381	136,622	472,621	11,474	6,631
1987	35.7%	45.1%	19.2%	322,530	406,745	172,979	902,254	18,111	7,702
1988	49.8%	29.6%	20.6%	247,609	146,987	102,553	497,149	9,966	6,953
1989	46.2%	40.6%	13.2%	338,101	296,596	96,559	731,256	17,045	5,549
1990	38.0%	41.5%	20.6%	211,974	231,542	114,958	558,475	11,333	5,627
1991	48.0%	32.9%	19.0%	367,658	252,016	145,821	765,495	11,046	6,391
1992	31.8%	48.6%	19.6%	132,645	202,723	81,589	416,957	8,790	3,538
1993	50.4%	35.7%	13.9%	199,588	141,522	55,280	396,390	5,973	2,333
1994	34.7%	47.5%	17.8%	307,685	420,581	157,982	886,248	10,966	4,119
1995	35.3%	47.9%	16.8%	446,834	607,347	212,538	1,266,720	10,302	3,605
1996	22.4%	59.6%	18.1%	207,224	552,416	167,464	927,104	9,275	2,812
1997	19.4%	59.6%	21.1%	106,006	325,921	115,239	547,166	7,094	2,508
1998	32.4%	47.0%	20.7%	92,361	134,027	59,023	285,412	2,401	1,057
1999	35.2%	35.8%	29.0%	125,153	127,448	103,100	355,701	3,229	2,612

Table 15. Reconstructed Yukon River fall chum salmon run by stock in at the mouth of the Yukon River, 1974-1999.

Year	Yukon River Run				Total Utilization in Districts Y1-Y4 and Portion of Y5 Below the Tanana River			
	Tanana River	Upper Yukon Tributaries	Upper Yukon Mainstem	Total Run	Tanana River	Upper Yukon Tributaries	Upper Yukon Mainstem	Total Utilization
1974	239,838	502,674	173,848	916,361	91,589	191,961	66,389	349,940
1975	209,714	1,357,620	370,941	1,938,275	36,954	239,230	65,365	341,548
1976	250,132	252,512	105,240	607,883	96,492	97,410	40,598	234,501
1977	335,886	461,429	165,446	962,761	113,483	155,899	55,898	325,280
1978	302,742	315,815	135,959	754,517	126,704	132,175	56,902	315,781
1979	450,799	689,834	255,562	1,396,195	138,461	211,880	78,495	428,836
1980	251,100	362,450	135,868	749,418	113,133	163,302	61,215	337,651
1981	440,422	574,651	213,377	1,228,450	180,706	235,781	87,549	504,037
1982	134,766	263,460	154,777	553,003	70,264	137,362	80,697	288,324
1983	254,609	334,579	282,985	872,173	103,720	136,298	115,280	355,298
1984	272,588	200,900	208,876	682,363	111,453	82,142	85,403	278,998
1985	334,768	649,884	195,256	1,179,907	91,991	178,582	53,654	324,227
1986	146,365	347,304	200,733	694,402	46,747	110,923	64,111	221,780
1987	378,235	476,996	202,855	1,058,086	55,705	70,251	29,876	155,832
1988	337,873	200,570	139,937	678,380	90,264	53,583	37,385	181,231
1989	484,250	424,803	138,298	1,047,351	146,148	128,207	41,739	316,094
1990	273,190	298,408	148,156	719,754	61,215	66,866	33,198	161,280
1991	494,806	339,171	196,251	1,030,228	127,148	87,155	50,430	264,733
1992	150,505	230,019	92,575	473,099	17,860	27,296	10,986	56,142
1993	223,411	158,414	61,878	443,704	23,823	16,892	6,598	47,314
1994	326,050	445,684	167,411	939,145	18,365	25,103	9,429	52,897
1995	535,032	727,228	254,490	1,516,750	88,198	119,881	41,952	250,030
1996	238,832	636,677	193,007	1,068,516	31,608	84,261	25,543	141,412
1997	125,721	386,535	136,670	648,926	19,715	60,614	21,432	101,760
1998	102,643	148,948	65,594	317,184	10,282	14,920	6,571	31,772
1999	148,559	151,284	122,382	422,225	23,406	23,836	19,282	66,524

Table 16. Total run by age, (1974–1999) and total recruits by age, (1974–1995 brood years) for aggregate Yukon River fall chum salmon. Recruits estimated for incomplete broods, (1994–1995 brood years).

			Return by Age				
Year	Catch	Escapement	Age 3	Age 4	Age 5	Age 6	Total Run
1974	478,875	437,486					916,361
1975	473,062	1,465,213					1,938,275
1976	339,043	268,841					607,883
1977	447,918	514,844	91,751	818,829	51,123	1,059	962,761
1978	434,030	320,487	150,451	497,755	105,180	1,132	754,517
1979	615,377	780,818	102,062	1,225,440	68,693	0	1,396,195
1980	488,305	261,113	102,370	585,820	61,227	0	749,418
1981	677,257	551,193	22,112	1,069,857	136,358	123	1,228,450
1982	373,175	179,828	41,088	332,023	175,578	4,313	553,003
1983	525,016	347,157	8,373	769,082	90,532	4,186	872,173
1984	412,322	270,041	45,855	362,199	274,310	0	682,363
1985	515,481	664,426	11,327	955,725	208,962	3,894	1,179,907
1986	318,028	376,374	12,569	400,323	278,386	3,125	694,402
1987	406,143	651,943	7,089	875,354	166,754	8,888	1,058,086
1988	353,242	325,138	46,605	407,774	223,323	678	678,380
1989	541,177	506,174	0	871,501	173,546	2,304	1,047,351
1990	350,100	369,654	12,380	428,614	270,268	8,493	719,754
1991	439,096	591,132	41,003	617,519	368,513	3,194	1,030,228
1992	148,846	324,253	2,744	175,236	290,766	4,353	473,099
1993	91,015	352,689	710	282,905	152,368	7,720	443,704
1994	169,225	769,920	3,663	579,452	345,136	10,894	939,145
1995	461,147	1,055,603	6,977	1,057,175	431,667	20,931	1,516,750
1996	260,923	807,593	8,548	667,823	360,838	31,308	1,068,516
1997	170,059	478,867	4,218	437,376	195,457	11,875	648,926
1998	70,773	246,411	2,252	213,909	96,836	4,187	317,184
1999	131,114	291,111	802	250,844	163,232	7,347	422,225

			Return by Age			Total
Brood Year	Escapement	Age 3	Age 4	Age 5	Age 6	Return
1974	437,486	91,751	497,755	68,693	0	658,199
1975	1,465,213	150,451	1,225,440	61,227	123	1,437,241
1976	268,841	102,062	585,820	136,358	4,313	828,553
1977	514,844	102,370	1,069,857	175,578	4,186	1,351,992
1978	320,487	22,112	332,023	90,532	0	444,667
1979	780,818	41,088	769,082	274,310	3,894	1,088,374
1980	261,113	8,373	362,199	208,962	3,125	582,658
1981	551,193	45,855	955,725	278,386	8,888	1,288,853
1982	179,828	11,327	400,323	166,754	678	579,082
1983	347,157	12,569	875,354	223,323	2,304	1,113,550
1984	270,041	7,089	407,774	173,546	8,493	596,902
1985	664,426	46,605	871,501	270,268	3,194	1,191,567
1986	376,374	0	428,614	368,513	4,353	801,479
1987	651,943	12,380	617,519	290,766	7,720	928,385
1988	325,138	41,003	175,236	152,368	10,894	379,501
1989	506,174	2,744	282,905	345,136	20,931	651,716
1990	369,654	710	579,452	431,667	31,308	1,043,137
1991	591,132	3,663	1,057,175	360,838	11,875	1,433,551
1992	324,253	6,977	667,823	195,457	4,187	874,443
1993	352,689	8,548	437,376	96,836	7,347	550,107
1994	769,920	4,218	213,909	163,232	**3,374**	384,733
1995	1,055,603	2,252	250,844	**94,140**		347,236

Table 17. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Tanana River chum salmon. Recruits estimated for incomplete broods, (1994–1995 brood years).

			Run by Age				
Year	Catch	Escapement	Age 3	Age 4	Age 5	Age 6	Total
1974	149,863	89,975					239,838
1975	87,036	122,678					209,714
1976	145,830	104,302					250,132
1977	163,545	172,341	32,010	285,671	17,836	369	335,886
1978	175,039	127,703	60,367	199,719	42,202	454	302,742
1979	224,412	226,387	32,953	395,666	22,179	0	450,799
1980	182,913	68,187	34,300	196,285	20,515	0	251,100
1981	233,327	207,094	7,928	383,563	48,887	44	440,422
1982	96,648	38,118	10,013	80,913	42,788	1,051	134,766
1983	169,983	84,626	2,444	224,514	26,428	1,222	254,609
1984	154,743	117,845	18,318	144,690	109,580	0	272,588
1985	171,306	163,462	3,214	271,162	59,287	1,105	334,768
1986	73,794	72,572	2,649	84,380	58,678	659	146,365
1987	183,608	194,627	2,534	312,914	59,610	3,177	378,235
1988	177,633	160,240	23,212	203,096	111,228	338	337,875
1989	279,999	204,250	0	402,944	80,240	1,065	484,250
1990	165,211	107,978	4,699	162,684	102,583	3,224	273,190
1991	213,450	281,356	19,693	296,587	176,992	1,534	494,806
1992	64,002	86,503	873	55,747	92,500	1,385	150,505
1993	33,839	189,572	357	142,447	76,719	3,887	223,411
1994	56,331	269,719	1,272	201,173	119,823	3,782	326,050
1995	212,346	322,686	2,461	372,917	152,270	7,383	535,032
1996	86,005	152,827	1,911	149,270	80,654	6,998	238,832
1997	39,549	86,172	817	84,736	37,867	2,301	125,721
1998	24,654	77,989	729	69,222	31,337	1,355	102,643
1999	39,139	109,420	282	88,259	57,433	2,585	148,559

		Return by Age				Total
Year	Escapement	Age 3	Age 4	Age 5	Age 6	Return
1974	89,975	32,010	199,719	22,179	0	253,908
1975	122,678	60,367	395,666	20,515	44	476,592
1976	104,302	32,953	196,285	48,887	1,051	279,176
1977	172,341	34,300	383,563	42,788	1,222	461,874
1978	127,703	7,928	80,913	26,428	0	115,269
1979	226,387	10,013	224,514	109,580	1,105	345,212
1980	68,187	2,444	144,690	59,287	659	207,080
1981	207,094	18,318	271,162	58,678	3,177	351,335
1982	38,118	3,214	84,380	59,610	338	147,541
1983	84,626	2,649	312,914	111,228	1,065	427,857
1984	117,845	2,534	203,096	80,240	3,224	289,094
1985	163,462	23,212	402,944	102,583	1,534	530,273
1986	72,572	0	162,684	176,992	1,385	341,061
1987	194,627	4,699	296,587	92,500	3,887	397,674
1988	160,240	19,693	55,747	76,719	3,782	155,942
1989	204,250	873	142,447	119,823	7,383	270,527
1990	107,978	357	201,173	152,270	6,998	360,798
1991	281,356	1,272	372,917	80,654	2,301	457,143
1992	86,503	2,461	149,270	37,867	1,355	190,953
1993	189,572	1,911	84,736	31,337	2,585	120,568
1994	269,719	817	69,222	57,433	**1,022**	128,495
1995	322,686	729	88,259	**33,210**		122,197

Table 18. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Upper Yukon River tributary fall chum salmon. Recruits estimated for incomplete broods, (1994 – 1995 brood years).

			Run by Age				
Year	Catch	Escapement	Age 3	Age 4	Age 5	Age 6	Total
1974	280,131	280,131					502,674
1975	275,391	1,082,228					1,357,620
1976	119,875	132,636					252,512
1977	185,334	276,094	43,974	392,445	24,502	508	461,429
1978	160,410	155,405	62,973	208,343	44,025	474	315,815
1979	242,903	446,931	50,427	605,467	33,940	0	689,834
1980	192,436	170,014	49,511	283,327	29,612	0	362,450
1981	277,618	297,032	10,344	500,464	63,786	57	574,651
1982	153,708	109,752	19,575	158,181	83,649	2,055	263,460
1983	162,922	171,656	3,212	295,031	34,729	1,606	334,579
1984	105,336	95,564	13,500	106,637	80,762	0	200,900
1985	210,929	438,954	6,239	526,406	115,094	2,145	649,884
1986	131,442	215,862	6,286	200,221	139,234	1,563	347,304
1987	100,456	376,540	3,196	394,619	75,175	4,007	476,996
1988	72,458	128,111	13,779	120,563	66,028	201	200,571
1989	158,630	266,173	0	353,479	70,390	935	424,803
1990	88,467	209,941	5,133	177,702	112,052	3,521	298,408
1991	107,856	231,315	13,499	203,299	121,322	1,051	339,171
1992	41,351	188,668	1,334	85,199	141,369	2,116	230,019
1993	25,040	133,373	253	101,005	54,399	2,756	158,414
1994	43,841	401,843	1,738	274,987	163,789	5,170	445,684
1995	152,403	574,825	3,345	506,878	206,969	10,036	727,228
1996	104,340	532,337	5,093	397,923	215,006	18,655	636,677
1997	79,279	307,256	2,512	260,525	116,424	7,074	386,535
1998	26,831	122,117	1,058	100,450	45,474	1,966	148,948
1999	35,489	115,795	287	89,878	58,486	2,632	151,284

		Return by Age				Total
Brood Year	Escapement	Age 3	Age 4	Age 5	Age 6	Return
1974	280,131	43,974	208,343	33,940	0	286,257
1975	1,082,228	62,973	605,467	29,612	57	698,111
1976	132,636	50,427	283,327	63,786	2,055	399,595
1977	276,094	49,511	500,464	83,649	1,606	635,229
1978	155,405	10,344	158,181	34,729	0	203,254
1979	446,931	19,575	295,031	80,762	2,145	397,513
1980	170,014	3,212	106,637	115,094	1,563	226,507
1981	297,032	13,500	526,406	139,234	4,007	683,147
1982	109,752	6,239	200,221	75,175	201	281,835
1983	171,656	6,286	394,619	66,028	935	467,868
1984	95,564	3,196	120,563	70,390	3,521	197,670
1985	438,954	13,779	353,479	112,052	1,051	480,362
1986	215,862	0	177,702	121,322	2,116	301,140
1987	376,540	5,133	203,299	141,369	2,756	352,558
1988	128,111	13,499	85,199	54,399	5,170	158,267
1989	266,173	1,334	101,005	163,789	10,036	276,163
1990	209,941	253	274,987	206,969	18,655	500,864
1991	231,315	1,738	506,878	215,006	7,074	730,695
1992	188,668	3,345	397,923	116,424	1,966	519,659
1993	133,373	5,093	260,525	45,474	2,632	313,724
1994	401,843	2,512	100,450	58,486	**1,561**	163,011
1995	574,825	1,058	89,878	**34,876**		125,811

Table 19. Total run by age, (1974 – 1999) and total recruits by age, (1974 – 1995 brood years) for Upper Yukon River mainstem fall chum salmon. Recruits estimated for incomplete broods, (1994 – 1995 brood years).

			Run by Age				
Year	Catch	Escapement	Age 3	Age 4	Age 5	Age 6	Total
1974	106,469	67,379					173,848
1975	110,635	260,307					370,941
1976	73,338	31,903					105,240
1977	99,038	66,408	15,767	140,712	8,785	182	165,446
1978	98,580	37,379	27,110	89,692	18,953	204	135,959
1979	148,062	107,500	18,682	224,306	12,574	0	255,562
1980	112,956	22,912	18,560	106,208	11,100	0	135,868
1981	166,311	47,066	3,841	185,830	23,685	21	213,377
1982	122,819	31,958	11,500	92,928	49,142	1,207	154,777
1983	192,110	90,875	2,717	249,536	29,374	1,358	282,985
1984	152,243	56,633	14,036	110,872	83,968	0	208,876
1985	133,246	62,010	1,874	158,157	34,580	644	195,256
1986	112,793	87,940	3,633	115,722	80,474	903	200,733
1987	122,079	80,776	1,359	167,822	31,970	1,704	202,855
1988	103,151	36,786	9,614	84,116	46,067	140	139,937
1989	102,548	35,750	0	115,078	22,916	304	138,298
1990	96,421	51,735	2,548	88,227	55,633	1,748	148,156
1991	117,790	78,461	7,811	117,633	70,199	608	196,251
1992	43,493	49,082	537	34,290	56,897	852	92,575
1993	32,135	29,743	99	39,454	21,249	1,077	61,878
1994	69,053	98,358	653	103,293	61,524	1,942	167,411
1995	96,398	158,092	1,171	177,380	72,428	3,512	254,490
1996	70,578	122,429	1,544	120,629	65,178	5,655	193,007
1997	51,231	85,439	888	92,116	41,165	2,501	136,670
1998	19,289	46,305	466	44,236	20,026	866	65,594
1999	56,486	65,896	233	72,707	47,313	2,129	122,382

		Return by Age				Total
Year	Escapement	Age 3	Age 4	Age 5	Age 6	Return
1974	67,379	15,767	89,692	12,574	0	118,033
1975	260,307	27,110	224,306	11,100	21	262,539
1976	31,903	18,682	106,208	23,685	1,207	149,782
1977	66,408	18,560	185,830	49,142	1,358	254,890
1978	37,379	3,841	92,928	29,374	0	126,143
1979	107,500	11,500	249,536	83,968	644	345,649
1980	22,912	2,717	110,872	34,580	903	149,071
1981	47,066	14,036	158,157	80,474	1,704	254,371
1982	31,958	1,874	115,722	31,970	140	149,707
1983	90,875	3,633	167,822	46,063	304	217,822
1984	56,633	1,359	84,108	22,916	1,748	110,132
1985	62,010	9,613	115,078	55,633	608	180,932
1986	87,940	0	88,227	70,199	852	159,278
1987	80,776	2,548	117,633	56,897	1,077	178,154
1988	36,786	7,811	34,290	21,249	1,942	65,291
1989	35,750	537	39,454	61,524	3,512	105,026
1990	51,735	99	103,293	72,428	5,655	181,475
1991	78,461	653	177,380	65,178	2,501	245,712
1992	49,082	1,171	120,629	41,165	866	163,831
1993	29,743	1,544	92,116	20,026	2,129	115,815
1994	98,358	888	44,236	47,313	**883**	93,320
1995	158,092	466	72,707	**27,157**		100,330

Table 20. Stock-recruitment relationship statistics for Yukon River fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years.

Stock-Recruitment Relationship Statistics	Ricker fit to data from 1974-1995 brood years	Autoregressive Ricker fit to data from 1974-1995 brood Years.	Ricker fit to data from 1980-1995 brood years
Ricker Alpha	3.6231	2.4108	5.2746
Ricker Beta	1.277E-06	7.836E-07	2.219E-06
Adjusted R-Square	0.4049	0.5506	0.5998
Significance of Relationship	0.0009	0.0002	0.0003
Lag 1 autocorrelation, Phi	0	0.705	0.000
No. of Brood Years	22	22	16
MSY Escapement Goal	413,346	492,293	287,469
Estimated Maximum Yield	470,209	314,645	513,753
Estimated MSY Exploitation Rate	53.2%	39.0%	64.1%
Maximum Recruitment	1,044,107	1,131,761	805,500
Spawners at Maximum Recruitment	783,358	1,276,129	450,660
Equilibrium Stock Size	1,008,439	1,122,922	749,405
Lower Escapement that produces 90% of MSY	270,225	327,150	185,107
Upper Escapement that produces 90% of MSY	578,201	676,950	407,900
Bootstrapped MSY Escapement Goal Statistics			
Mean	425,900	422,795	290,599
Standard Deviation	76,782	80,035	35,882
Coefficient of Variation	18.0%	18.9%	12.3%
Lower 90% C.I.	327,662	335,745	239,411
Upper 90% C.I.	557,317	533,105	354,353
Indicated Bias	12,554	-69,498	3,130
Indicated % Bias	2.9%	-16.4%	1.1%

Table 21. Stock-recruitment relationship statistics for Tanana River fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years and for Ricker model fit to data from 1980 to 1995 brood years.

Stock-Recruitment Relationship Statistics	Ricker fit to data from 1974-1995 brood years	Ricker fit to data from 1980-1995 brood years
Ricker Alpha	6.5956	6.2428
Ricker Beta	7.284E-06	7.648E-06
Adjusted R-Square	0.5560	0.6377
Significance of Relationship	4.11421E-05	0.000126378
Lag 1 autocorrelation, Phi	0	0
No. of Brood Years	22	16
MSY Escapement Goal	95,287	92,571
Estimated Maximum Yield	218,649	226,721
Estimated MSY Exploitation Rate	69.6%	71.0%
Maximum Recruitment	333,094	300,305
Spawners at Maximum Recruitment	137,280	130,762
Equilibrium Stock Size	258,965	252,031
Lower Escapement that produces 90% of MSY	60,846	58,989
Upper Escapement that produces 90% of MSY	136,302	131,982
Bootstrapped MSY Escapement Goal Statistics		
Mean	96,606	93,462
Standard Deviation	12,002	11,463
Coefficient of Variation	12.4%	12.3%
Lower 90% C.I.	80,745	77,322
Upper 90% C.I.	117,771	113,865
Indicated Bias	1,319	891
Indicated % Bias	1.4%	1.0%

Table 22. Stock-recruitment relationship statistics for Upper Yukon River tributary fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years.

Stock-Recruitment Relationship Statistics	Ricker fit to data from 1974–1995 brood years	Autoregressive Ricker fit to data from 1974-1995 brood years	Ricker fit to data from 1980-1995 brood years
Ricker Alpha	2.9302	2.1153	4.2696
Ricker Beta	2.017E-06	1.470E-06	4.330E-06
Adjusted R-Square	0.3777	0.5130	0.6018
Significance of Relationship	0.0014	0.0004	0.0003
Lag 1 autocorrelation, Phi	0	0.655	0.000
No. of Brood Years	22	22	16
MSY Escapement Goal	226,337	228,097	140,817
Estimated Maximum Yield	193,751	116,940	223,442
Estimated MSY Exploitation Rate	46.1%	33.9%	61.3%
Maximum Recruitment	534,309	529,365	362,789
Spawners at Maximum Recruitment	495,665	680,272	230,972
Equilibrium Stock Size	532,876	509,649	360,334
Lower Escapement that produces 90% of MSY	149,252	152,335	91,044
Upper Escapement that produces 90% of MSY	313,873	311,806	199,053

Bootstrapped MSY Escapement Goal Statistics			
Mean	230,816	221,822	141,501
Standard Deviation	40,066	34,368	16,757
Coefficient of Variation	17.4%	15.5%	11.8%
Lower 90% C.I.	174,845	168,649	118,601
Upper 90% C.I.	307,493	298,830	172,409
Indicated Bias	4,479	-6,275	684
Indicated % Bias	1.9%	-2.8%	0.5%

Table 23. Stock-recruitment relationship statistics for Upper Yukon River mainstem fall chum salmon for Ricker model fit to data from 1974 to 1995 brood years, Autoregressive Ricker model fit to data from 1974 – 1999 brood years, and for Ricker model fit to data from 1980 to 1995 brood years.

Stock-Recruitment Relationship Statistics	Ricker fit to data from 1974–1995 brood years	Autoregressive Ricker fit to data from 1974-1995 brood years	Ricker fit to data from 1980-1995 brood years
Ricker Alpha	5.0256	3.9511	6.4880
Ricker Beta	7.889E-06	6.041E-06	1.445E-05
Adjusted R-Square	0.4848	0.5981	0.6594
Significance of Relationship	0.0002	0.0001	0.0001
Lag 1 autocorrelation, Phi	0	0.622	0.000
No. of Brood Years	22	22	16
MSY Escapement Goal	79,199	91,852	48,770
Estimated Maximum Yield	133,890	116,521	117,682
Estimated MSY Exploitation Rate	62.8%	55.9%	70.7%
Maximum Recruitment	232,825	240,624	165,157
Spawners at Maximum Recruitment	126,758	165,544	69,195
Equilibrium Stock Size	204,657	227,457	133,714
Lower Escapement that produces 90% of MSY	51,095	59,716	31,092
Upper Escapement that produces 90% of MSY	112,178	129,074	69,877
Bootstrapped MSY Escapement Goal Statistics			
Mean	81,663	79,353	49,100
Standard Deviation	13,419	11,196	5,848
Coefficient of Variation	16.4%	14.1%	11.9%
Lower 90% C.I.	62,493	59,968	40,116
Upper 90% C.I.	106,458	103,695	58,751
Indicated Bias	2,465	-12,499	331
Indicated % Bias	3.0%	-15.8%	0.7%

Table 24. Tables of Markov transition probabilities for average yields over regular ranges of spawners. Tables presented for Yukon River and Tanana River fall chum salmon, based on spawner-recruit data for 1974 – 1995 brood years.

Yukon River Fall Chum Salmon						
Spawner Interval	N	Mean Spawners	Recruits/ Spawner	Mean Yield	Range of Yield	
0-200	1	179,828	3.22	399,254	399,254	
100-300	4	244,956	2.69	401,842	321,545	559,712
200-400	10	321,574	2.25	399,925	54,373	766,390
300-500	11	332,111	2.18	389,842	54,373	766,390
400-600	5	520,166	2.04	556,697	145,543	837,148
500-700	6	579,952	1.98	561,059	145,543	837,148
600-800	4	716,777	1.28	181,488	-385,187	527,140
700-900	2	775,369	0.95	-38,815	-385,187	307,556
800-1000	2	775,369	0.95	-38,815	-385,187	307,556
900-1100	1	1,055,603	0.33	-708,367	-708,367	
>1100	1	1,465,213	0.98	-27,972	-27,972	

Tanana River Fall Chum Salmon						
Spawner Interval	N	Mean Spawners	Recruits/ Spawner	Mean Yield	Range of Yield	
0-50	1	38,118	3.87	109,423	109,423	
25-75	3	59,625	3.87	172,269	109,423	268,490
50-100	5	80,372	3.56	203,800	104,450	343,231
75-125	7	101,987	3.21	223,496	104,450	353,914
100-150	6	116,101	2.65	188,085	-12,434	353,914
125-175	4	155,937	1.95	159,903	-12,434	366,811
150-200	5	176,048	1.92	157,218	-69,004	366,811
175-225	4	198,886	1.43	86,140	-69,004	203,047
200-250	3	212,577	1.52	109,781	66,276	144,241
>250	3	291,254	0.83	-55,309	-200,489	175,787

Table 25. Tables of Markov transition probabilities for average yields over regular ranges of spawners. Tables presented for Upper Yukon River tributary and Upper Yukon River mainstem fall chum salmon, based on spawner-recruit data for 1974 – 1995 brood years.

Upper Yukon River Tributary Fall Chum Salmon						
Spawner Interval	N	Mean Spawners	Recruits/ Spawner	Mean Yield	Range of Yield	
0-100	1	95,564	2.07	102,107	102,107	
50-150	5	119,887	2.25	150,331	30,156	266,959
100-200	8	148,702	2.16	172,637	30,156	330,991
150-250	7	191,837	2.15	229,589	47,850	499,381
200-300	7	253,793	1.94	233,850	6,126	499,381
250-350	4	279,858	1.67	190,341	6,126	386,115
300-400	1	376,540	0.94	-23,982	-23,982	
350-450	4	416,067	0.83	-67,706	-238,832	41,407
400-500	3	429,243	0.80	-82,281	-238,832	41,407
>500	2	828,527	0.43	-416,566	-449,014	-384,118

Upper Yukon River Mainstem Fall Chum Salmon						
Spawner Interval	N	Mean Spawners	Recruits/ Spawner	Mean Yield	Range of Yield	
0-20	0					
10 - 30	2	26,328	5.20	106,116	86,072	126,159
20 - 40	7	32,346	3.98	90,631	28,515	126,159
30 - 50	7	38,559	3.74	106,320	28,515	207,305
40 - 60	4	51,129	3.55	126,323	53,499	207,305
50 - 70	5	60,833	2.79	108,259	50,654	188,481
60 - 80	4	68,565	2.91	131,327	50,654	188,481
70 - 90	3	82,392	2.38	111,989	71,338	167,251
80 - 100	4	89,487	1.84	72,656	-5,038	126,947
>100	3	175,299	1.62	60,873	-57,762	238,149

Table 26. Portion of years when annual escapements for fall chum salmon stocks within the Yukon River were below, within, or above the biological escapement goal ranges recommended in this report.

Stock	Recommended Biological Escapement Goal Range	Years When Escapement Was Below Recommended Level	Years When Escapement Was Within Recommended Level	Years When Escapement Was Above Recommended Level
Tanana River	**61,000 to 136,000** Total Spawners	1 of 26 Years 3.8% 0 since 1990	13 of 26 years 50% 5 since 1990	12 of 26 years 46.2% 5 since 1990
Toklat River	**15,000 to 33,000** Total Spawners	6 of 26 Years 23.1% 4 since 1990	11 of 26 Years 42.3% 3 since 1990	9 of 26 Years 34.6% 3 since 1990
Delta River	**6,000 to 13,000** Total Spawners	4 of 26 Years 15.4% 0 since 1990	10 of 26 years 38.5% 4 since 1990	12 of 26 years 46.2% 6 since 1990
Upper Yukon River Tributaries	**152,000 to 312,000** Total Spawners	7 of 26 Years 26.9% 3 since 1990	12 of 26 years 46.2% 4 since 1990	7 of 26 Years 26.9% 3 since 1990
Chandalar River	**74,000 to 152,000** Total Spawners	6 of 26 Years 23.1% 1 since 1990	12 of 26 years 46.2% 5 since 1990	8 of 26 Years 30.8% 4 since 1990
Sheenjek River	**50,000 to 104,000** Total Spawners	9 of 26 Years 34.6% 3 since 1990	9 of 26 years 34.6% 4 since 1990	8 of 26 Years 30.8% 3 since 1990
Fishing Branch River	**27,000 to 56,000** Total Spawners	7 of 26 Years 26.9% 4 since 1990	12 of 26 years 46.2% 4 since 1990	7 of 26 Years 26.9% 2 since 1990
Upper Yukon River Mainstem	**60,000 to 129,000** Total Spawners	12 of 26 Years 46.2% 4 since 1990	12 of 26 years 46.2% 5 since 1990	2 of 26 Years 7.7% 1 since 1990
Aggregate Yukon River	**300,000 to 600,000** Total Spawners	6 of 26 Years 23.1% 2 since 1990	13 of 26 years 50% 5 since 1990	7 of 26 Years 26.9% 3 since 1990

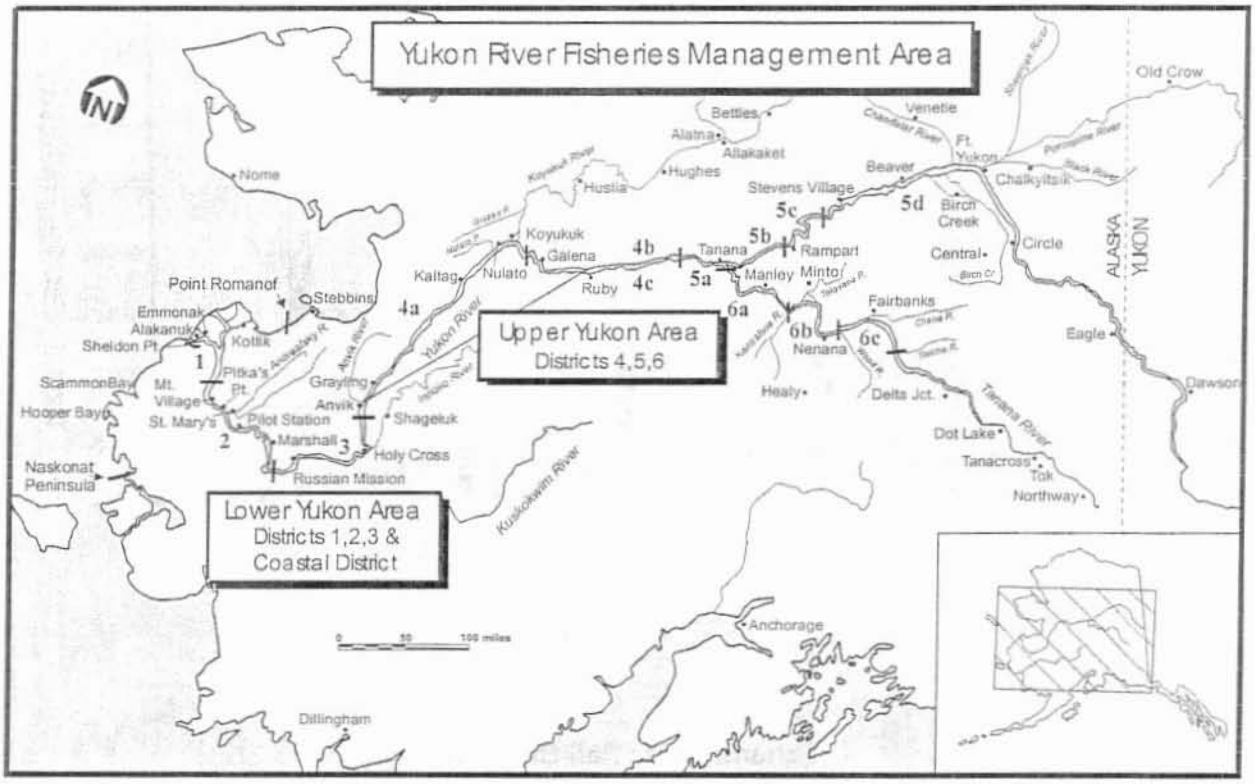


Figure 1. The Yukon Area showing communities and fishing districts, 2000.

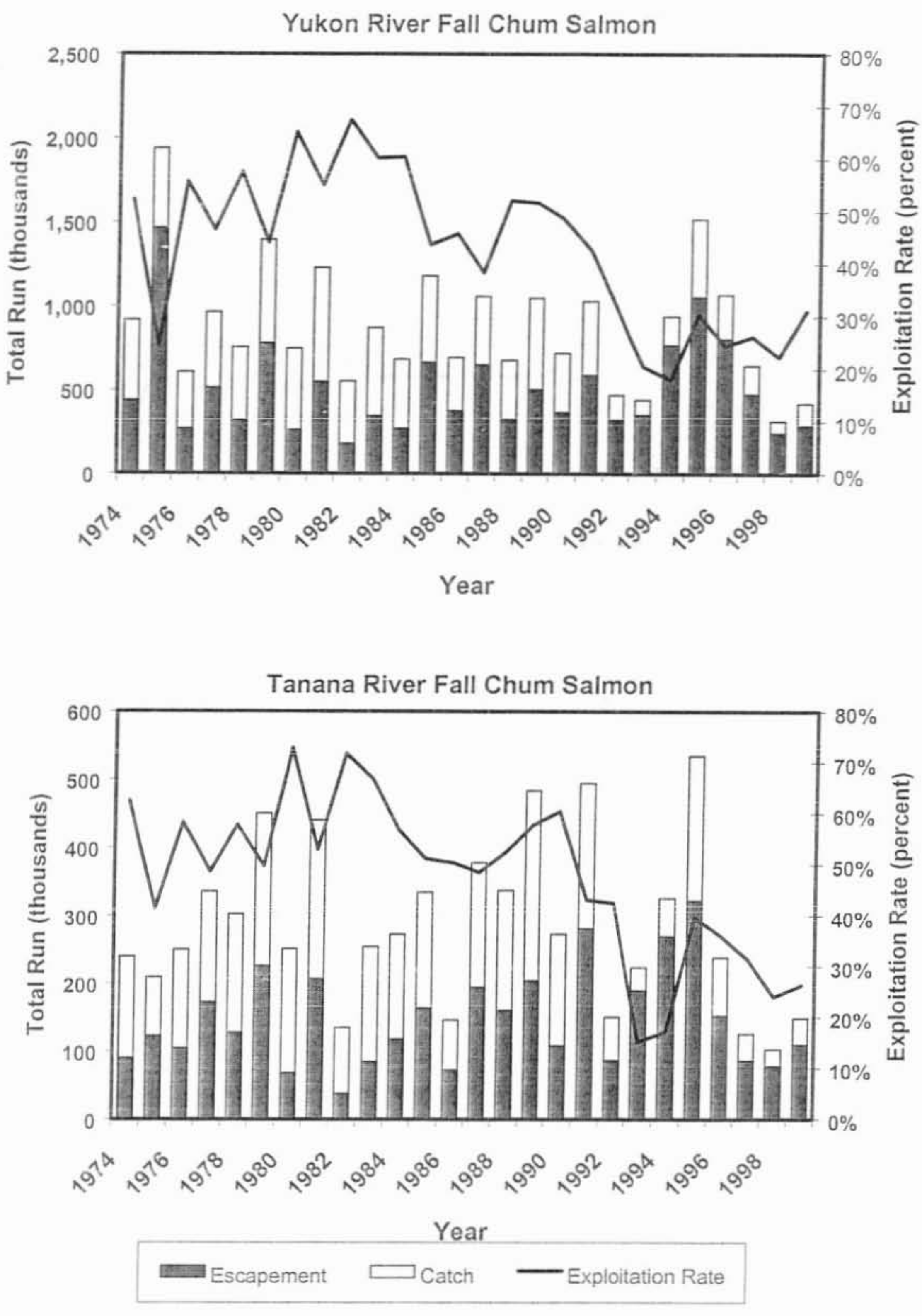


Figure 2. Top panel is estimated escapement, catch, and exploitation rate for the Yukon River fall chum salmon run, 1974 to 1999. Lower panel is estimated catch, escapement, and exploitation rate for Tanana River fall chum salmon, 1974 to 1999.

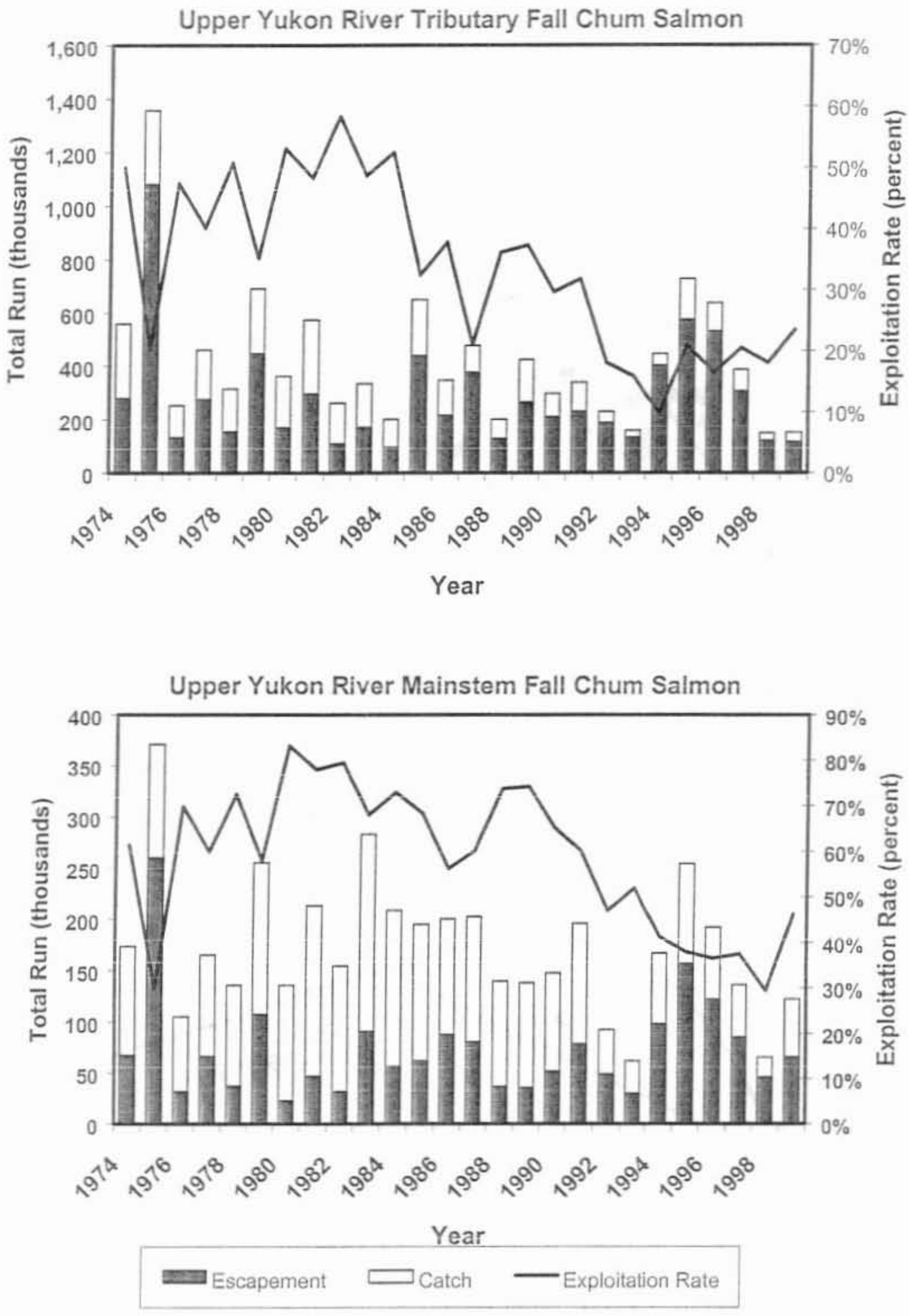


Figure 3. Top panel is estimated escapement, catch, and exploitation rate for the Upper Yukon River tributary fall chum salmon run, 1974 to 1999. Lower panel is estimated catch, escapement, and exploitation rate for Upper Yukon River mainstem fall chum salmon, 1974 to 1999.

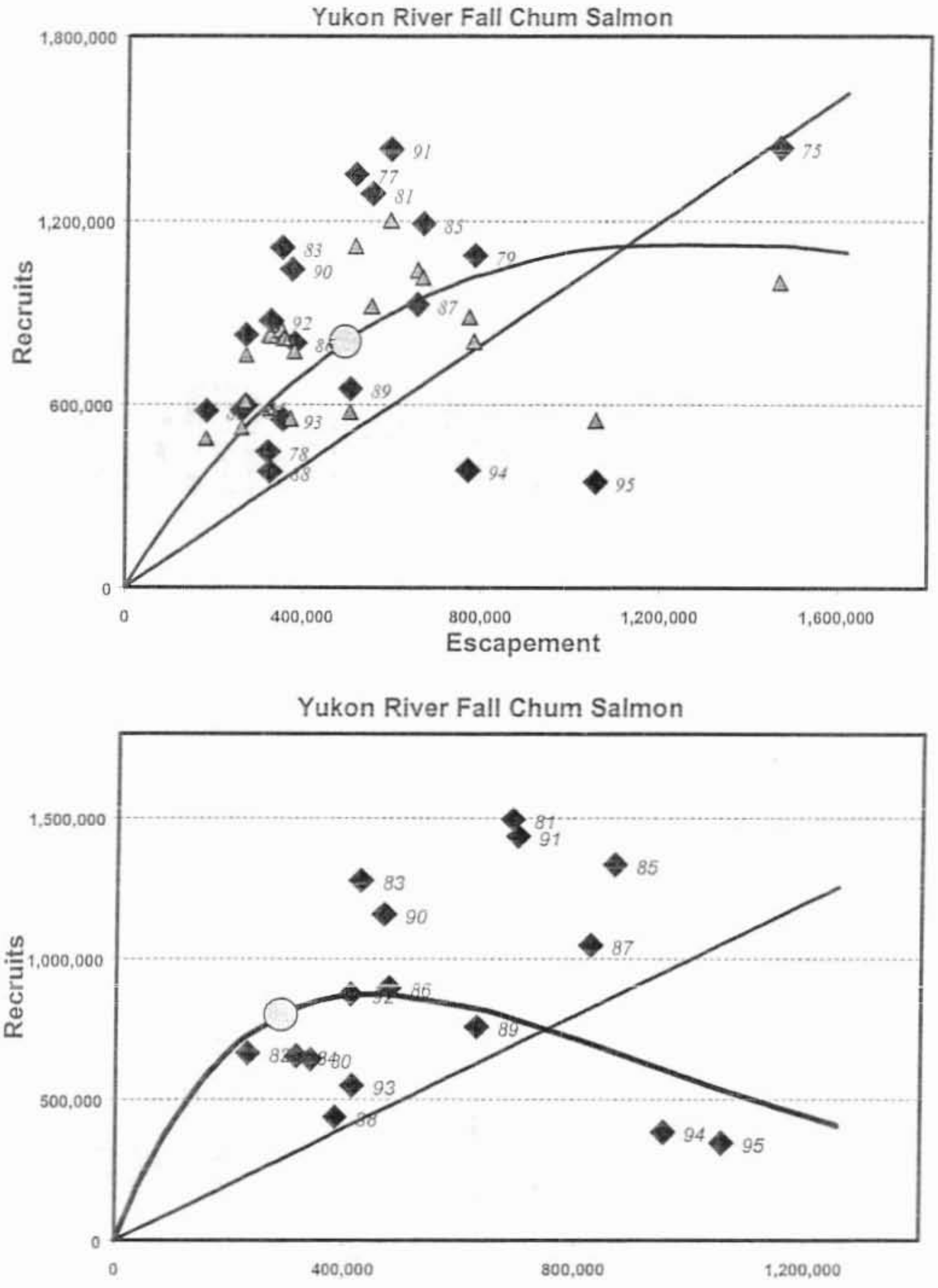


Figure 4. Upper panel is auto-regressive Ricker stock recruitment relationship for Yukon River fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Yukon River fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).

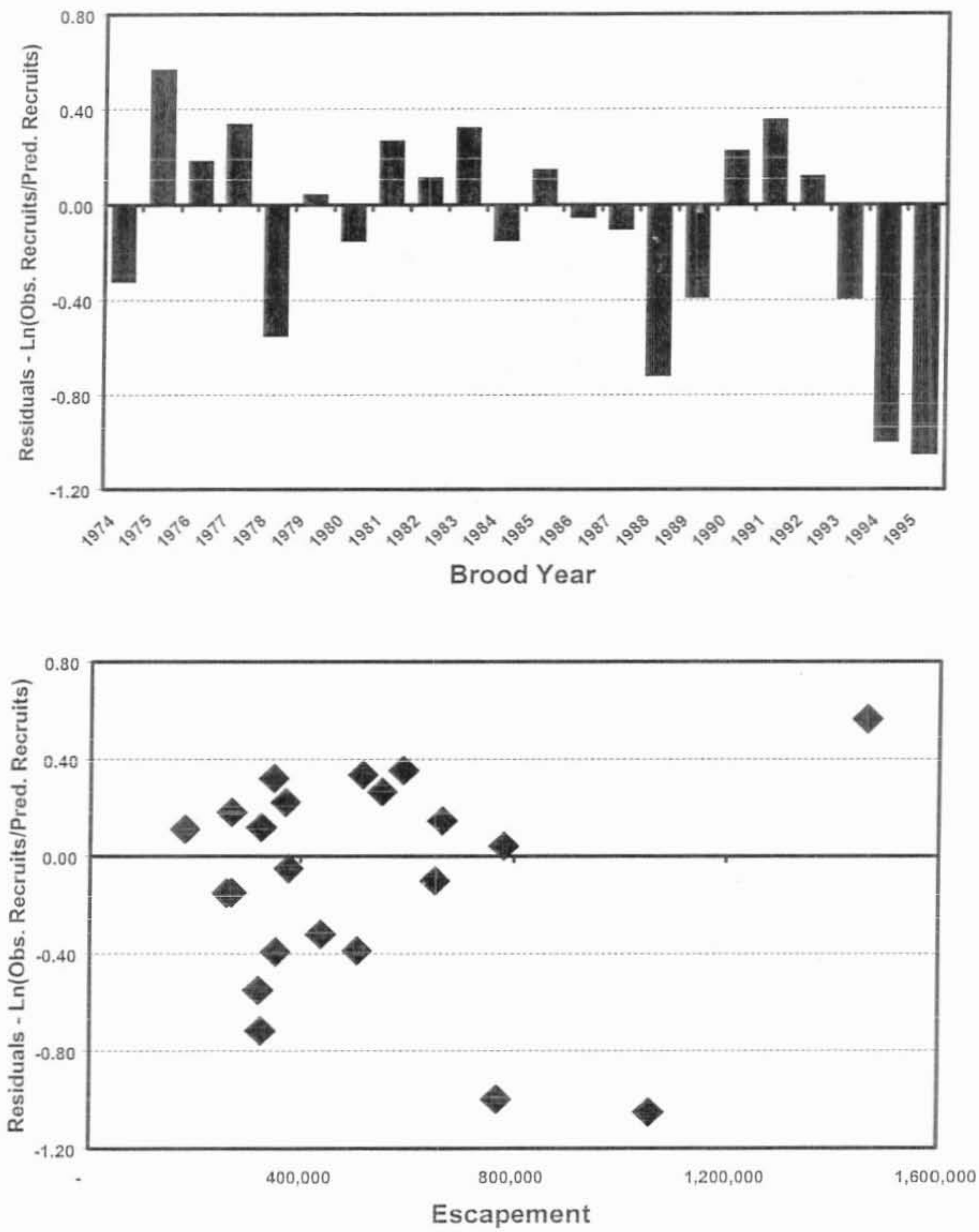


Figure 5. Residual plots for the Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

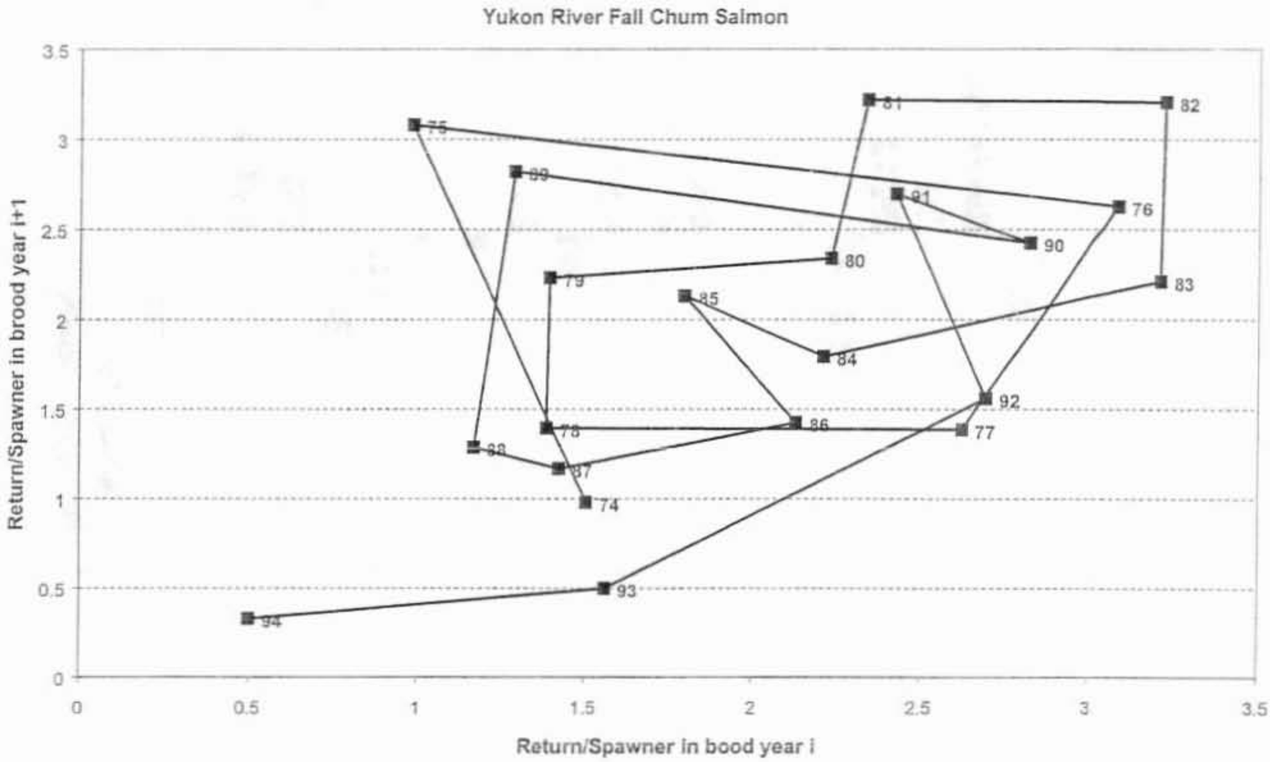


Figure 6. Return per spawner observed for a brood year versus the return per spawner observed for previous brood year. Labels for individual points are the brood year.

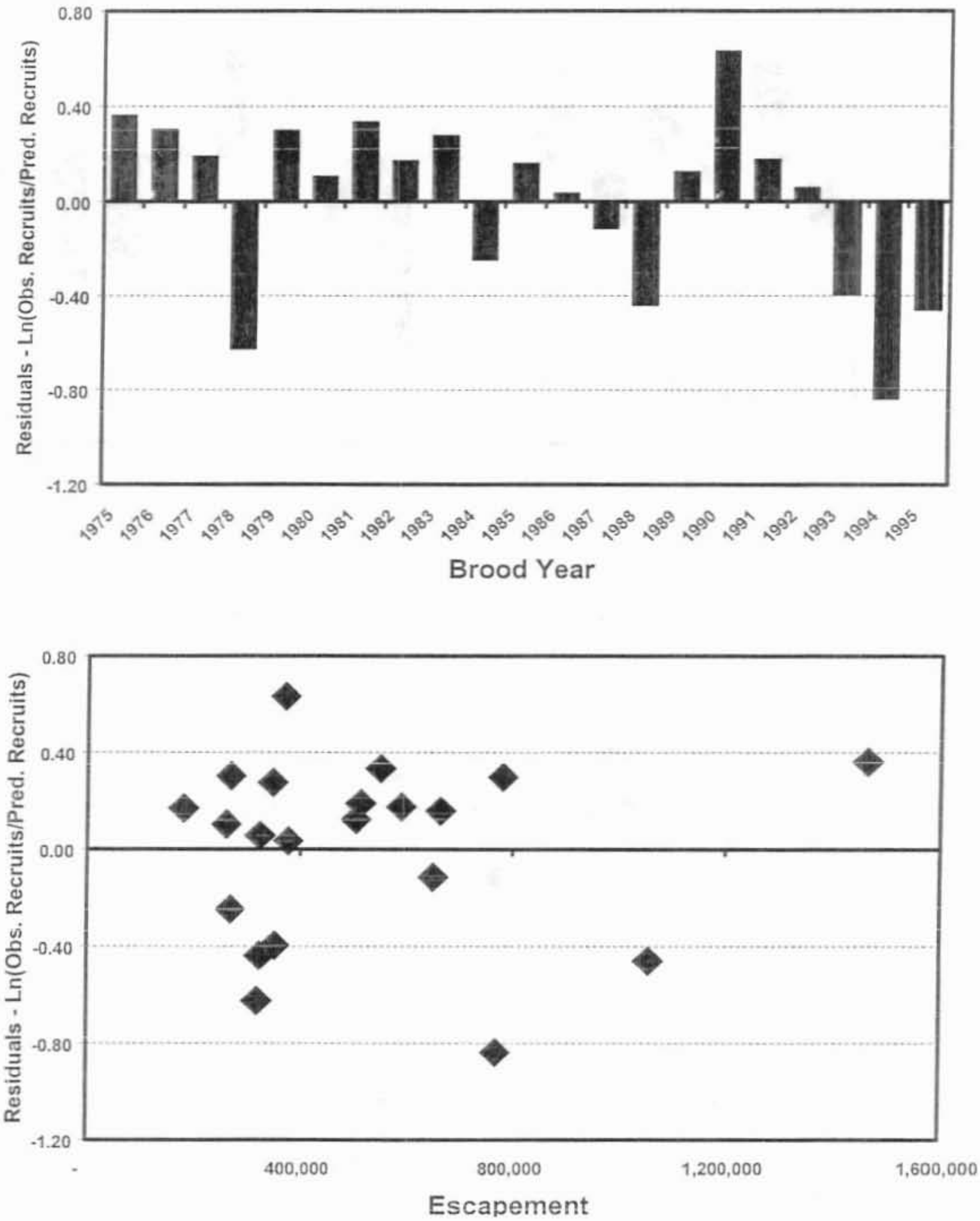


Figure 7. Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

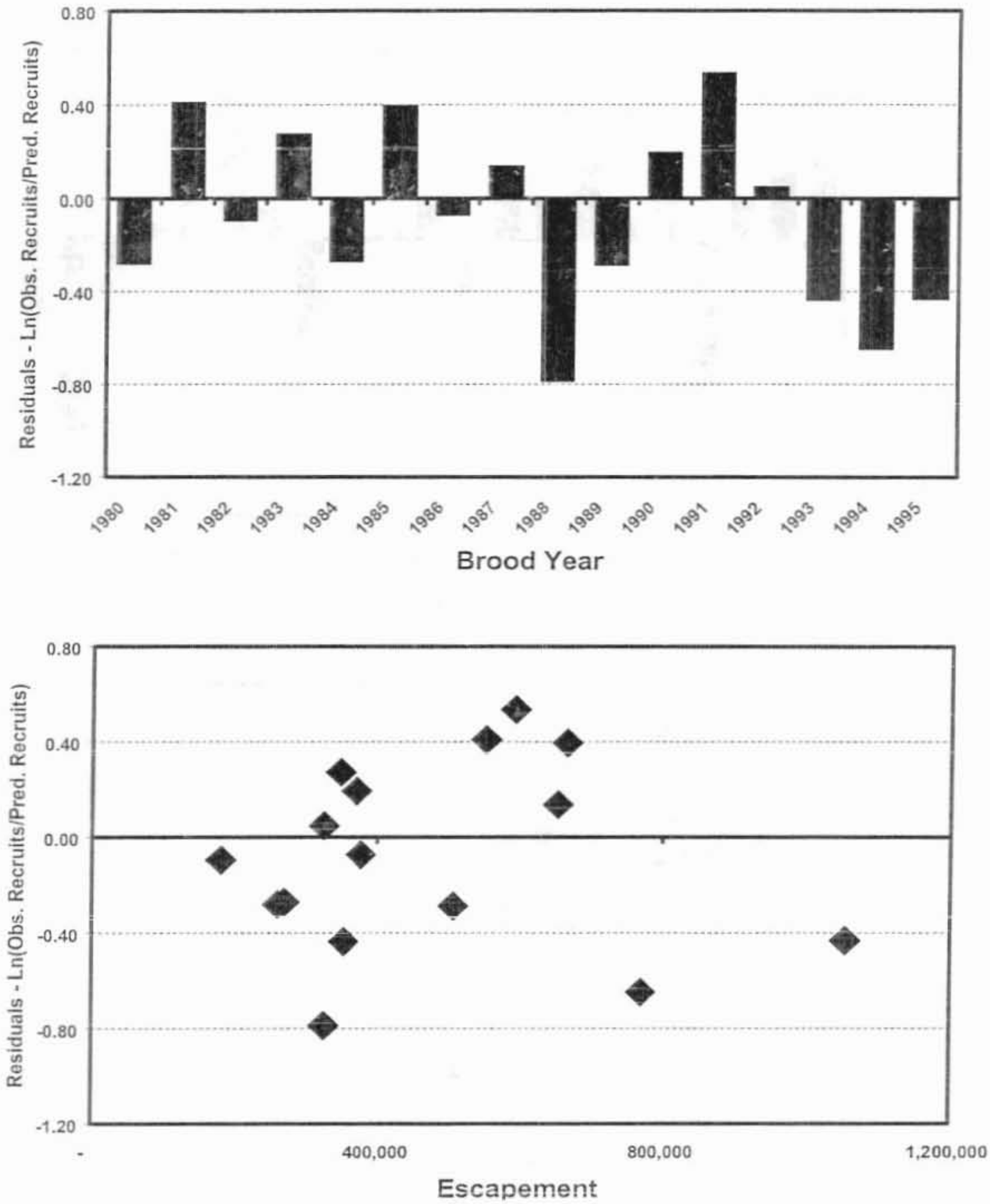


Figure 8. Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Yukon River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

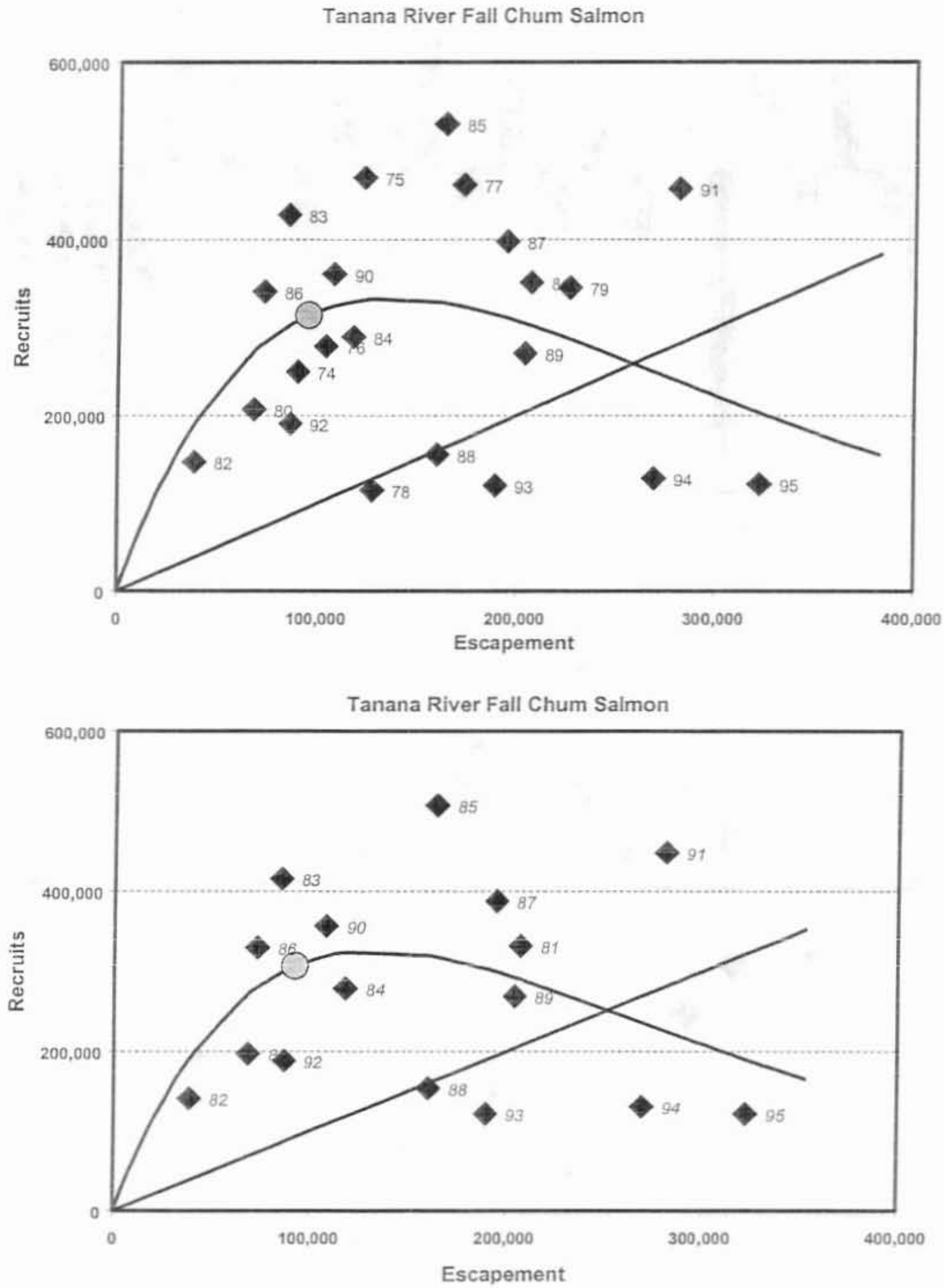


Figure 9. Upper panel is Ricker stock recruitment relationship for Tanana River fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, solid line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Tanana River fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).

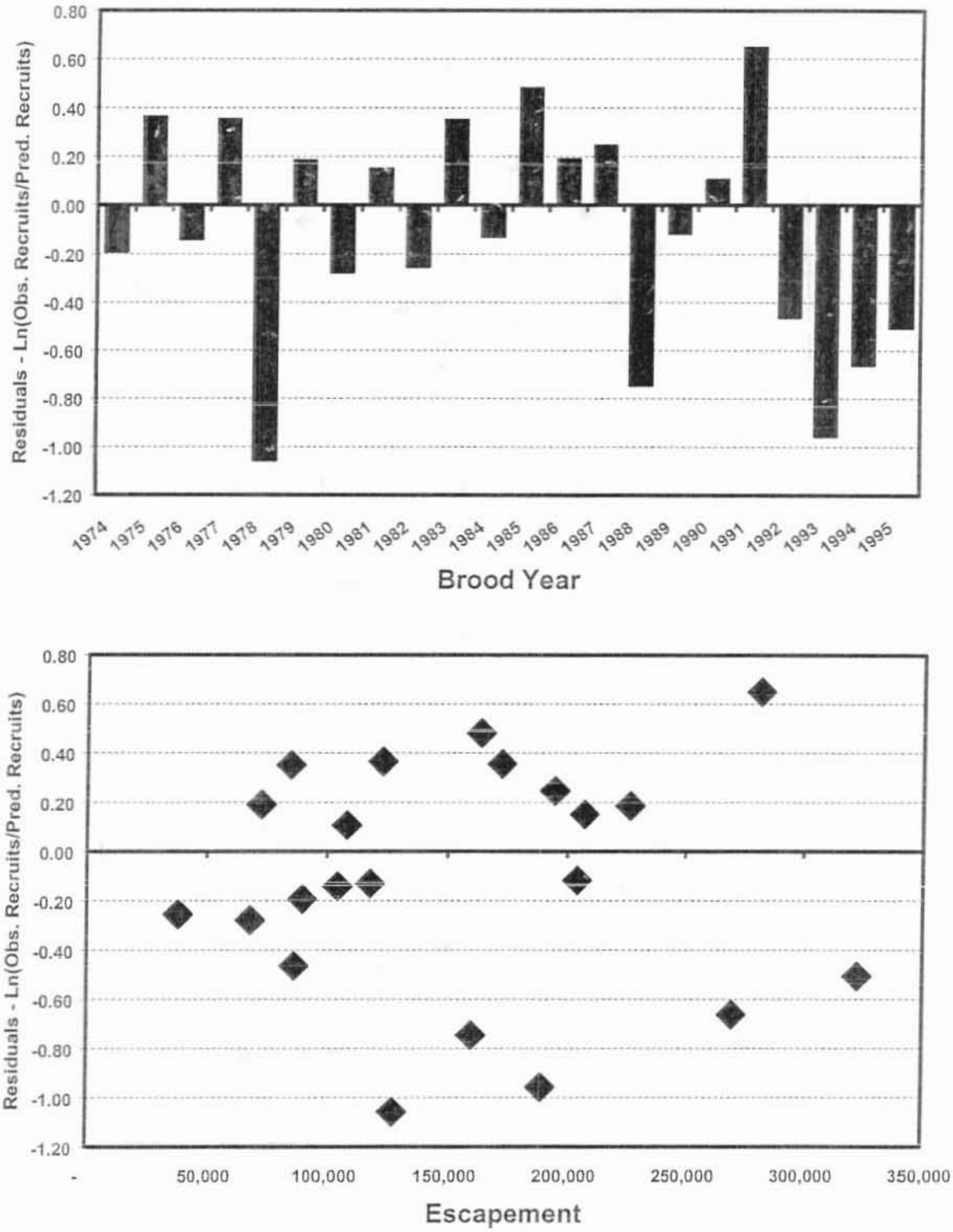


Figure 10.Residual plots for the Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Tanana River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

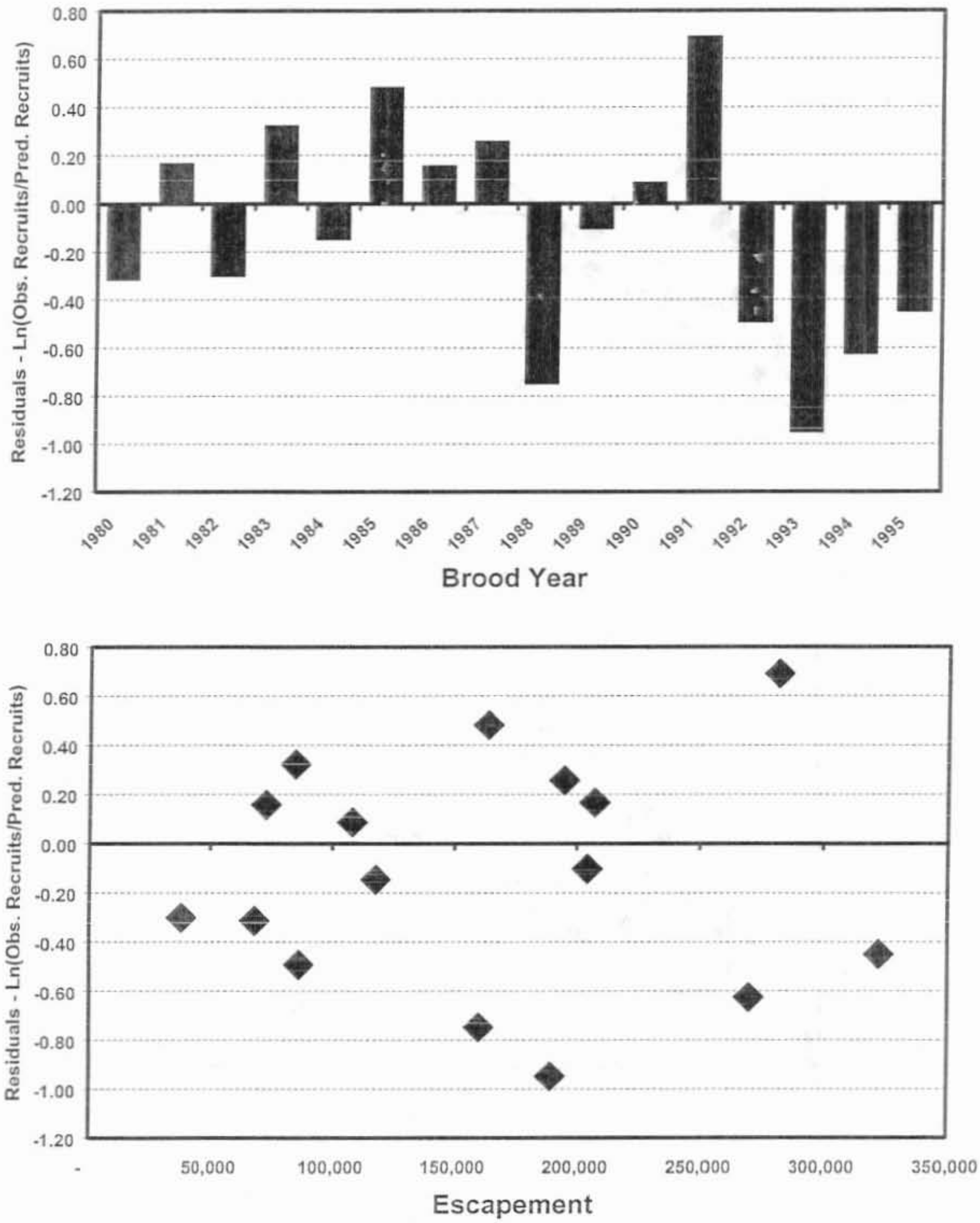
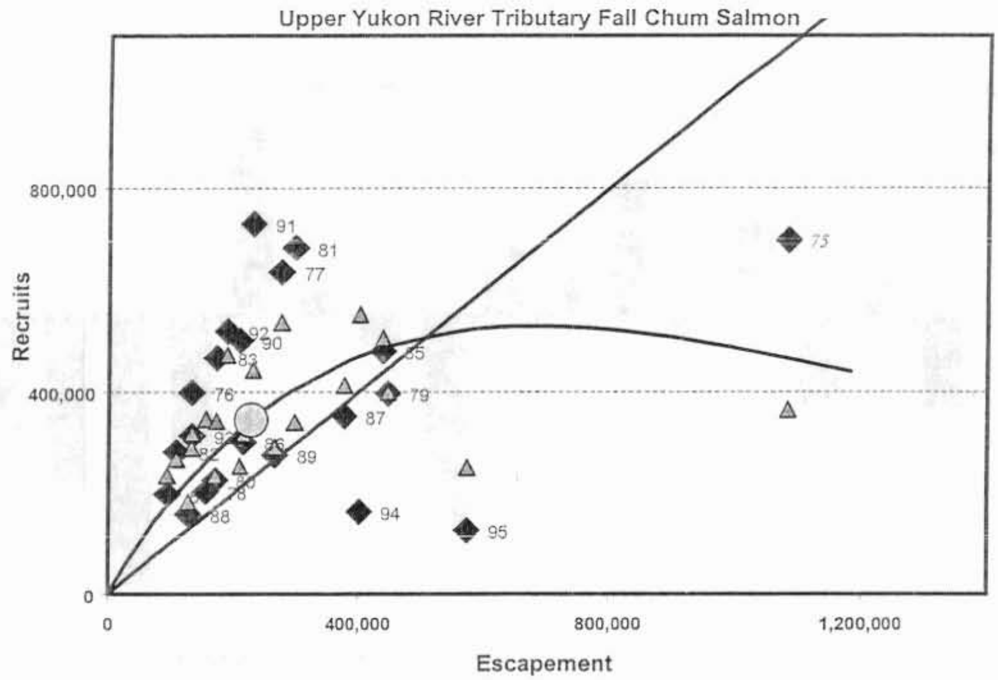


Figure 11.Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Tanana River fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.



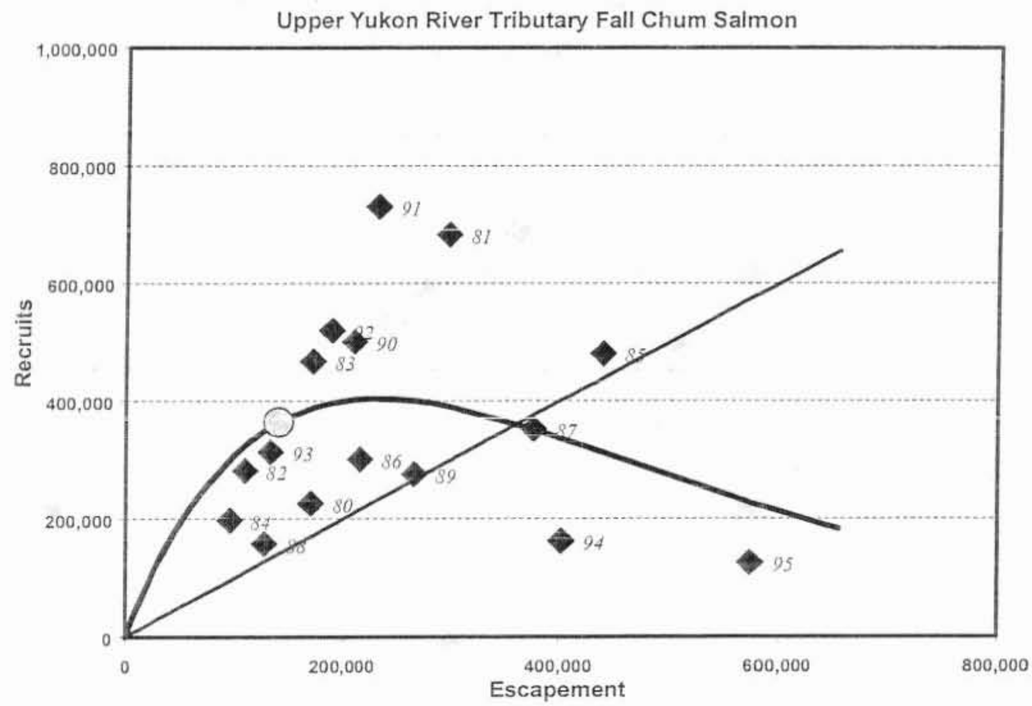


Figure 12.Upper panel is auto-regressive Ricker stock recruitment relationship for UpperYukon River tributary fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Upper Yukon River tributary fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).

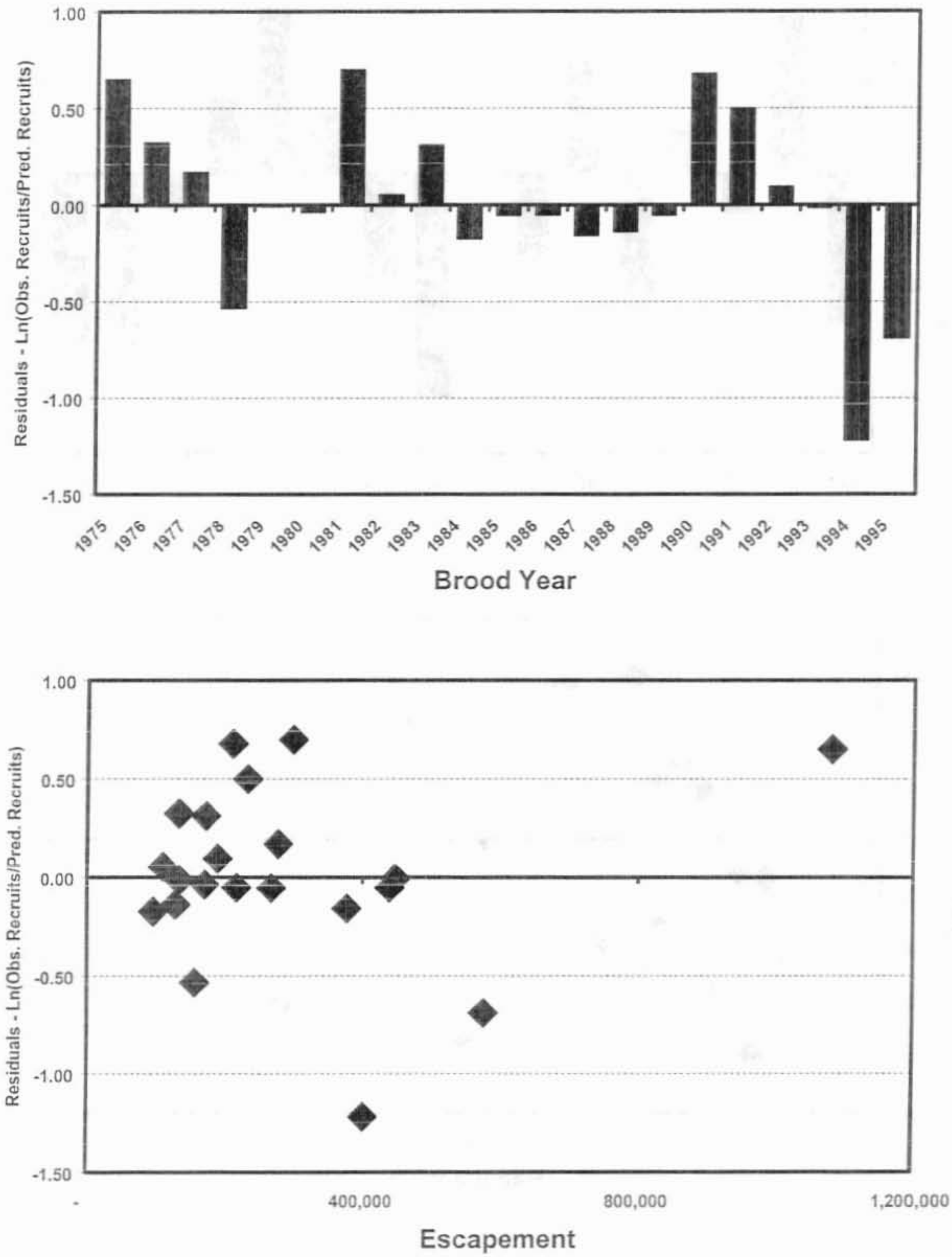


Figure 13.Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Upper Yukon River tributary fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

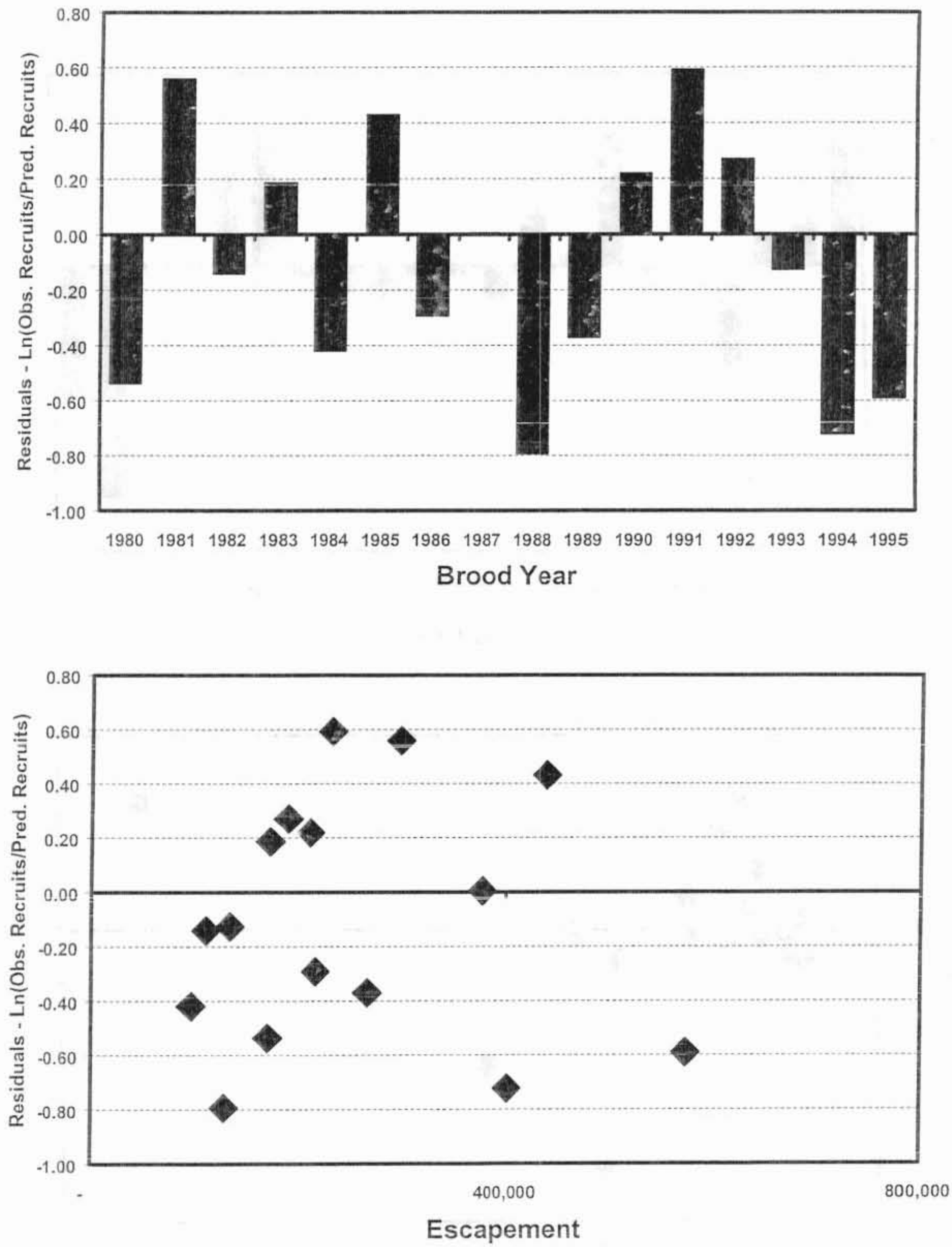


Figure 14.Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Upper Yukon River tributary fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

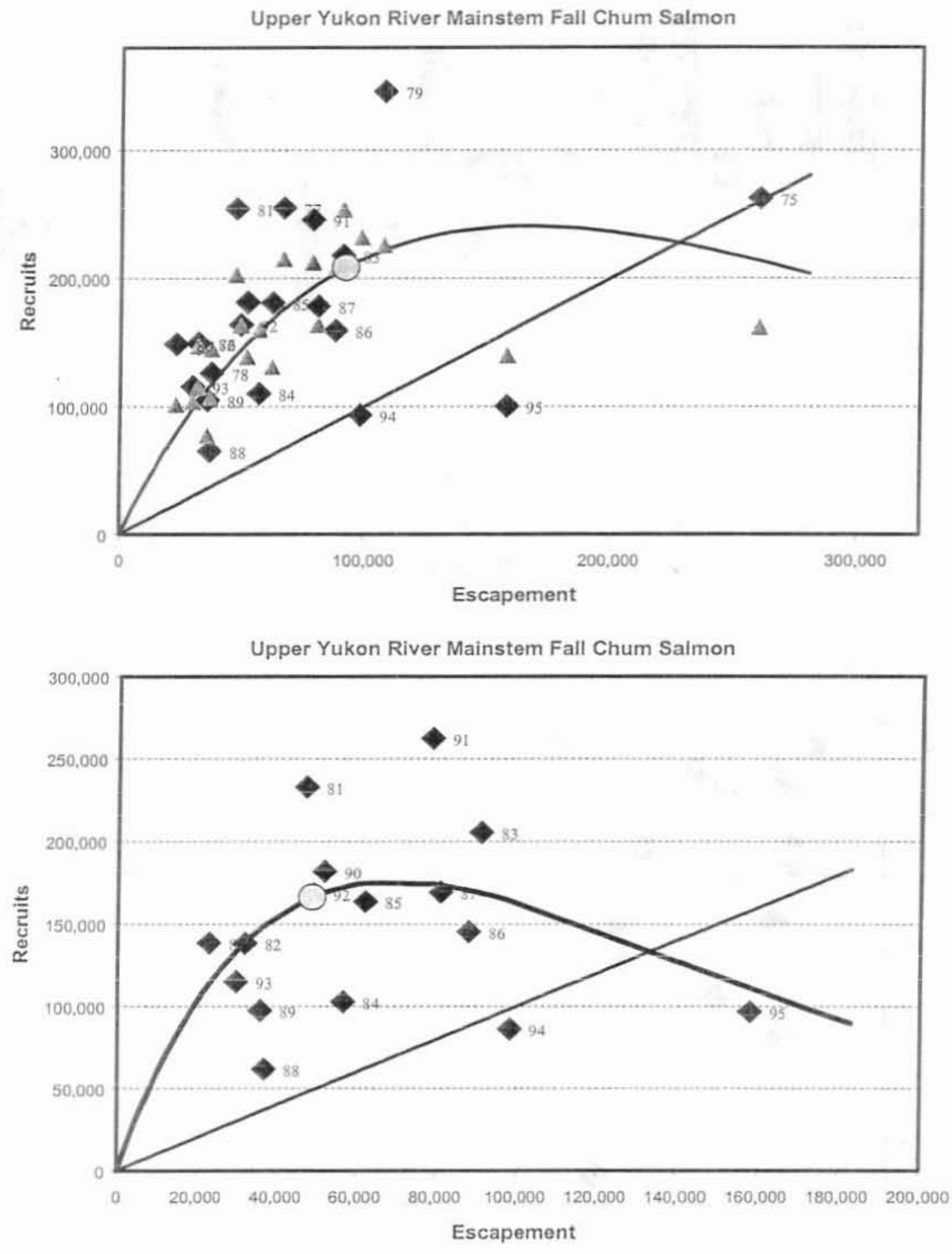


Figure 15.Upper panel is auto-regressive Ricker stock recruitment relationship for UpperYukon River mainstem fall chum salmon fit to 1974 to 1995 brood years (diamonds are observed recruits from parent escapement, triangles are predicted recruits, solid line is replacement, and circle is estimated recruits at MSY escapement). Lower panel is Ricker stock recruitment relationship for Upper Yukon River mainstem fall chum salmon fit to 1980 to 1995 brood years (diamonds are observed recruits from parent escapement, line is predicted recruits and replacement, and circle is estimated recruits at MSY escapement).

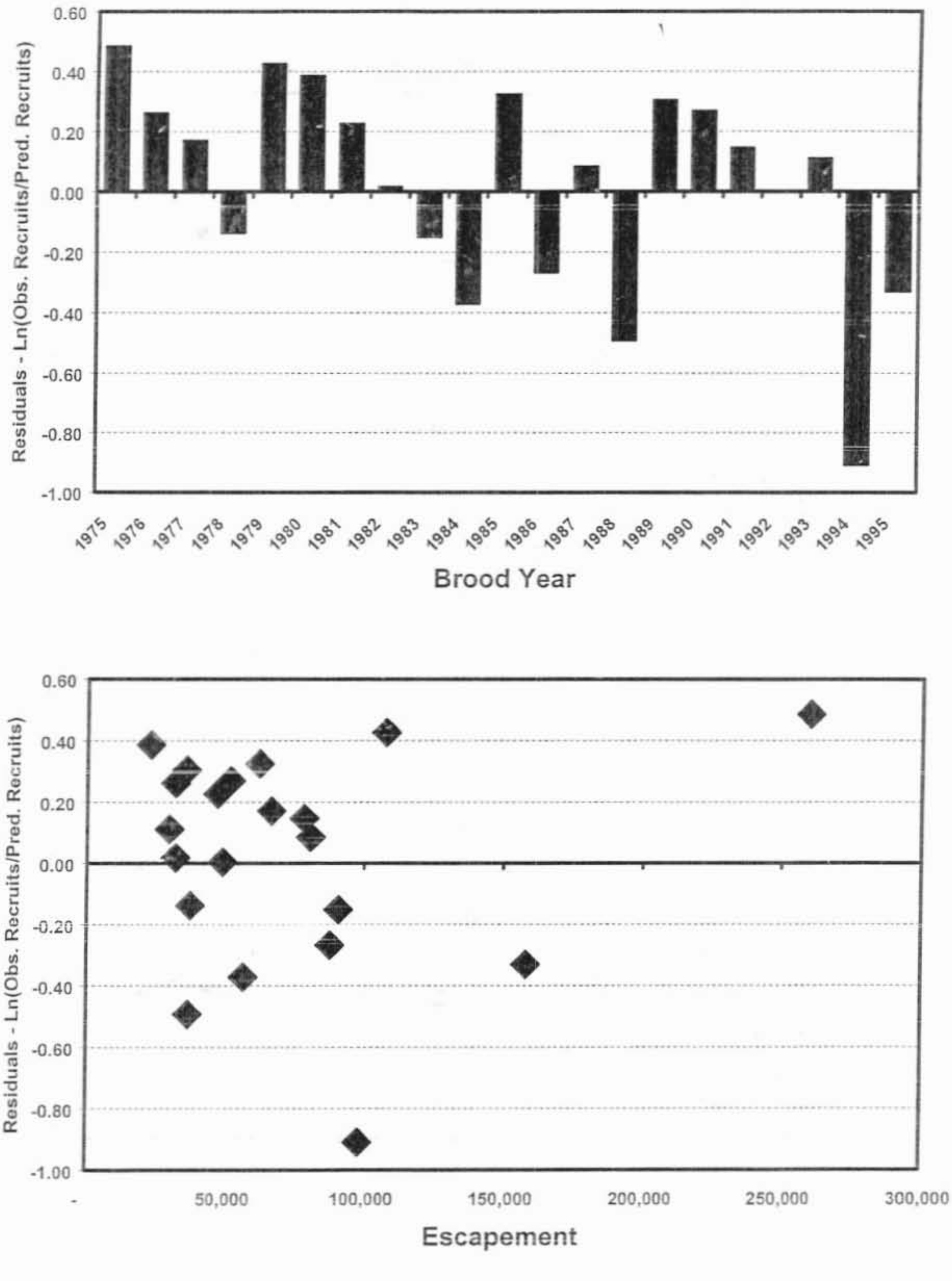


Figure 16.Residual plots for the auto-regressive Ricker spawner-recruit relationship fit to the 1974 to 1995 brood years, for Upper Yukon River mainstem fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

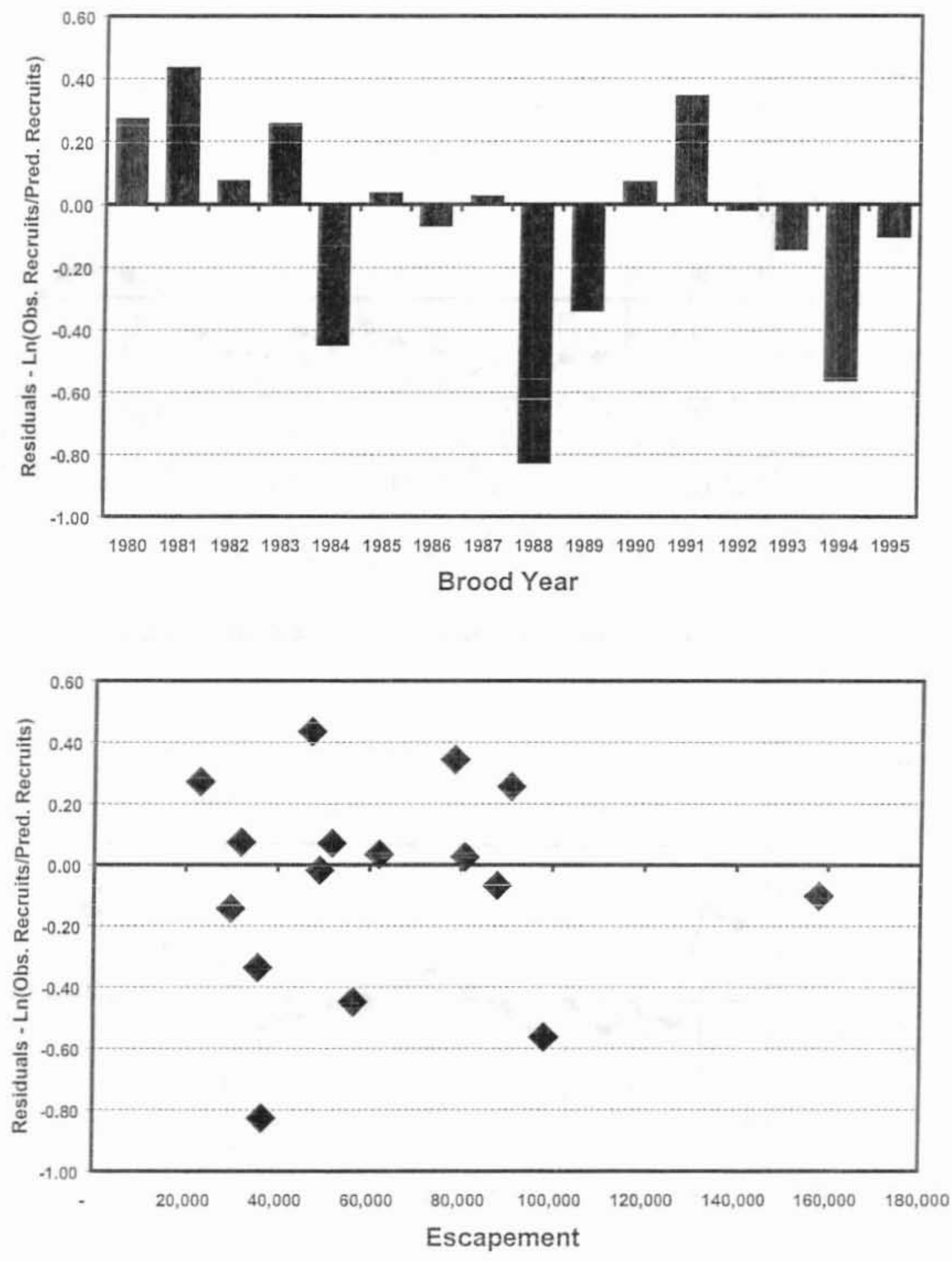


Figure 17.Residual plots for the Ricker spawner-recruit relationship fit to the 1980 to 1995 brood years, for Upper Yukon River mainstem fall chum salmon. Upper panel is the residuals versus brood year and lower panel is the residuals versus escapement.

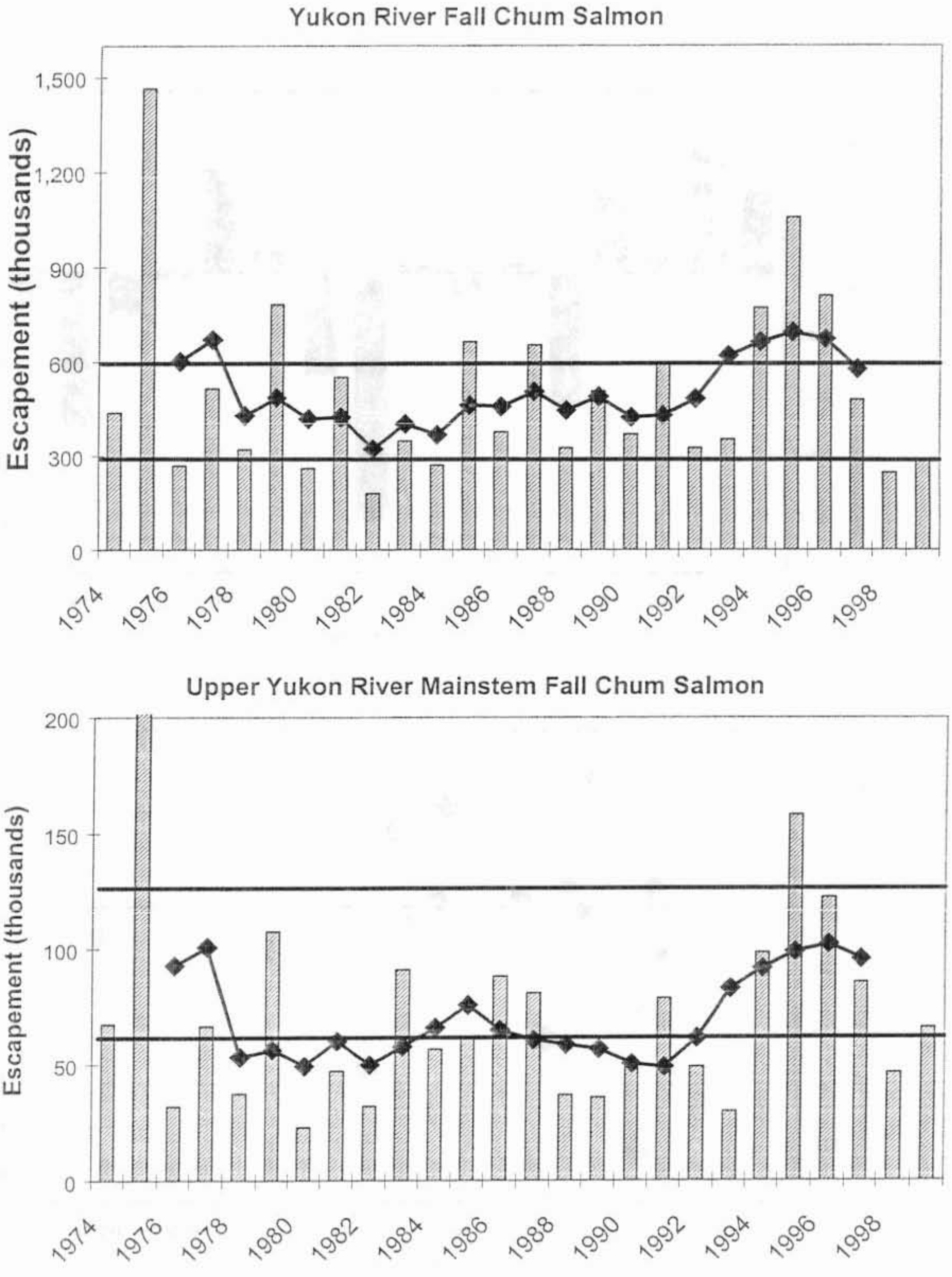


Figure 18. Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for aggregate Yukon River fall chum salmon, and Upper Yukon River mainstem fall chum salmon.

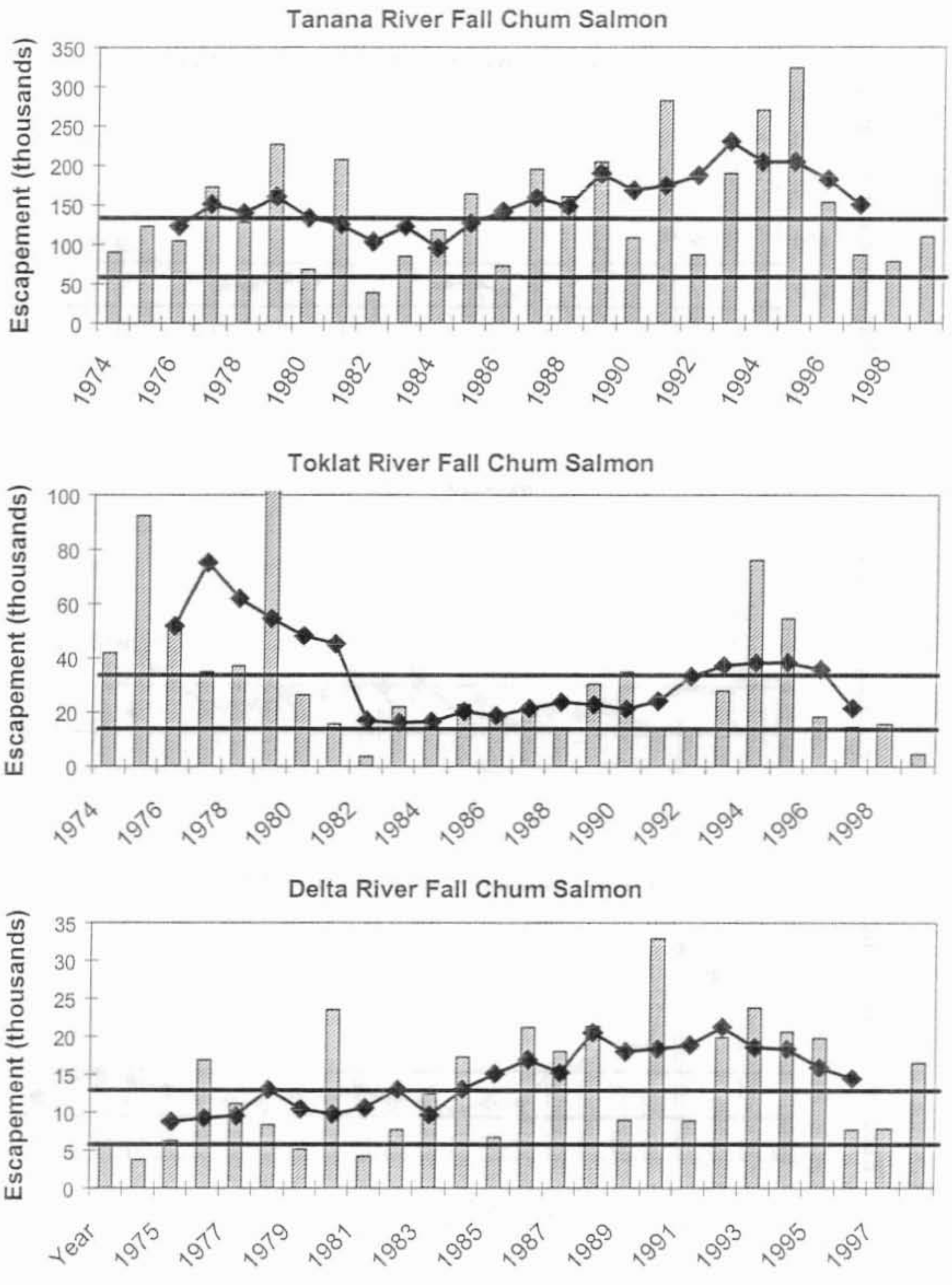


Figure 19. Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for Tanana River fall chum salmon, Toklat River fall chum salmon, and Delta River fall chum salmon.

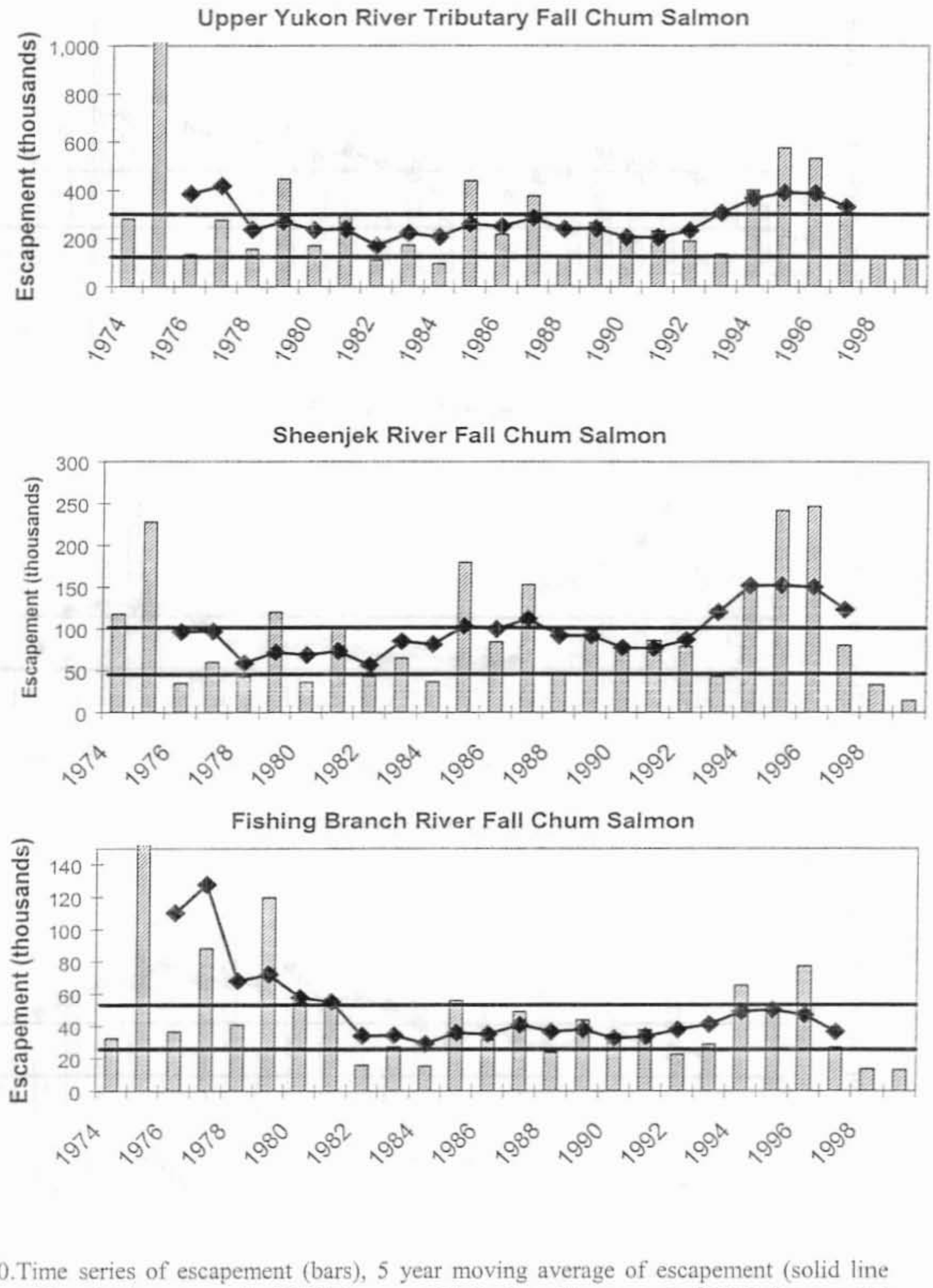


Figure 20. Time series of escapement (bars), 5 year moving average of escapement (solid line with points), upper end of BEG (upper solid line), and lower end of BEG (lower solid line), for Upper Yukon River tributary fall chum salmon, Sheenjek River fall chum salmon, and Fishing Branch River fall chum salmon.